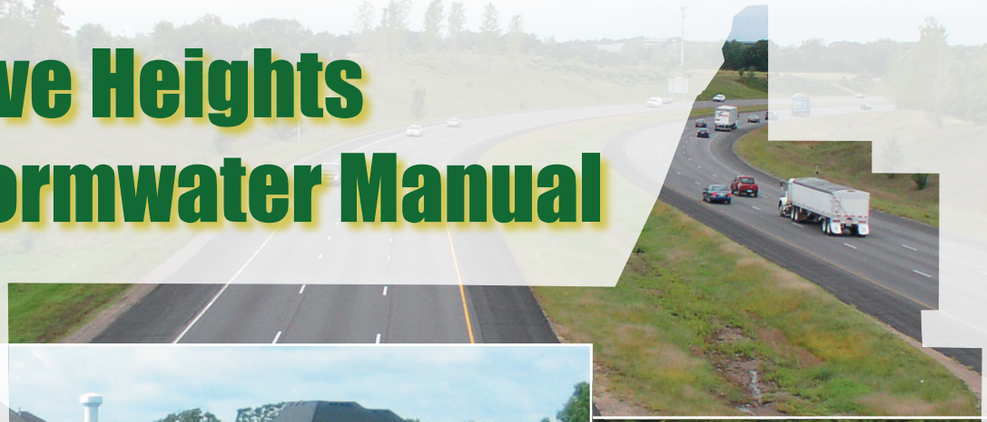
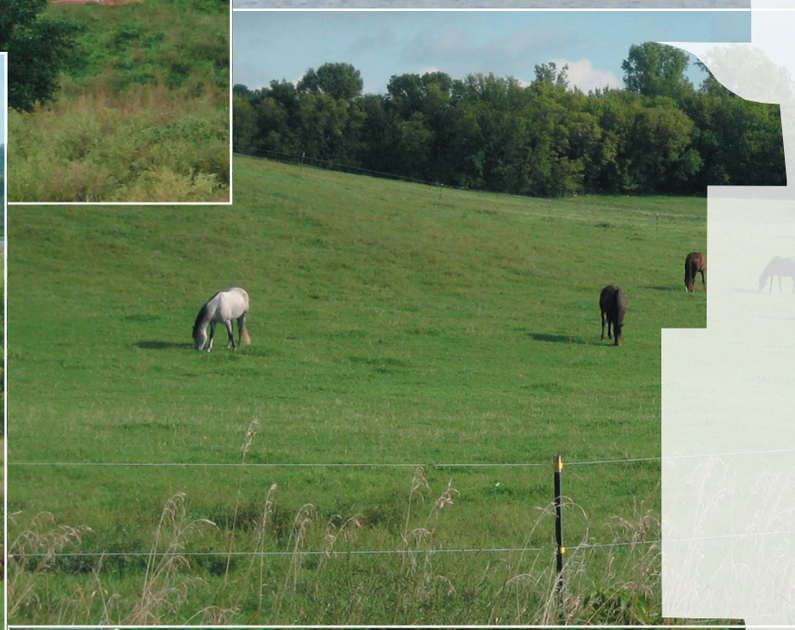
Inver Grove Heights Stormwater Manual











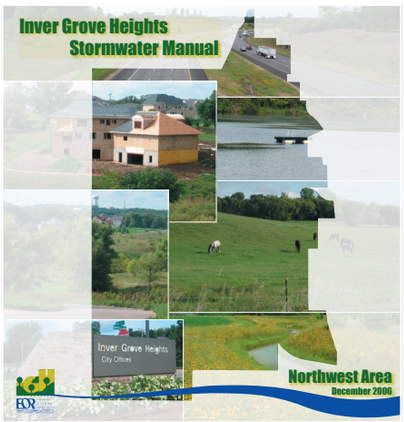




EOR EMMONS & OLIVIER RESOURCES

Northwest Area

December 2006



Inver Grove Heights
Stormwater Manual - Northwest Area

EMMONS & OLIVIER RESOURCES

December 2006

Table of Contents

Executive Summary

Chapter 1: Purpose and Use of the Manual

I. Vision and Goal of the City of Inver Grove Heights' Northwest Area 3
II. Relationship between NWA Stormwater Design Manual and the Minnesota Stormwater Manual 7
III. NWA Stormwater Design Manual Organization 7

Chapter 2: Unique Features of the Northwest Area (NWA)

I. Introduction 3
II. Climate 3
III. Geology 4
IV. Ground Water 6
V. Drinking Water 6
VI. Watersheds 8
VII. Soils 12
VIII. Topography 16
IX. Wetlands 19
X. Lakes and Ditches 23
XI. Landlocked Basins 25
XII. Uplands 27
XIII. Parks and Trails 29
XIV. References 31

Chapter 3: Integrating Stormwater Management Into Site Design

I. What is Stormwater? 3
II. Integrated Stormwater Management 6
III. Integrated Stormwater Management Process 9
IV. Link to Better Site Design 14
V. References 15

Chapter 4: Better Site Design Techniques

I. Introduction 3
II. Preserving Natural Areas 3
III. Disconnecting and Distributing Stormwater 7
IV. Reducing Impervious Cover in Site Design 9
V. The Benefits of Better Site Design 14
VI. Applying Better Site Design 15
VII. References 19

Chapter 5: Best Management Practices

I. Introduction 3
II. Using the Treatment Train Approach to BMP Selection 3
III. Process for Selecting Best Management Practices 7

III. BMP Selection Matrix 21
IV. References 25

Chapter 6: Additional Design Considerations

I. Introduction 3
II. Cold Climate 3
III. Potential Stormwater Hotspots (PSHs) 20
IV. Mosquito Control 26
V. References 28

Chapter 7: Stormwater Sizing Criteria

I. Introduction 3
II. Overview of NWA Stormwater Sizing Framework 3
III. Volume Control (Recharge and Infiltration) Standard 5
IV. Peak Discharge (Rate Control) Standard 5
V. Water Quality/Pretreatment Standard 6
VI. Wetland Bounce Standard 10
VII. Stormwater Sizing Redevelopment Projects 13
VIII. References 13

Chapter 8: Details of Stormwater Best Management Practices (BMPs)

I. Introduction 5
II. Fact Sheets and Design Guidance 5
III. NWA Design Influences 6
IV. Design Guidance – Overview 8
V. The Role of Pretreatment 9
VI. The Importance of Maintenance 11
VII. Fact Sheets 12
Pollution Prevention – Residential Practices 13
Pollution Prevention – Municipal Practices 15
Pollution Prevention – Industrial & Commercial Practices 17
Better Site Design – Overview 21
Better Site Design – Residential Streets & Parking Lots 23
Better Site Design – Lot Development 25
Better Site Design – Conservation of Natural Areas 27
Temporary Construction Erosion and Sediment Control 29
VIII. Guidance Documents 35
Green Roofs 36
Rainwater Harvesting 46
Pervious Surfaces 54
Filtration 64
Bioretention 88
Infiltration Practices 110
Stormwater Ponds 132
Stormwater Wetlands 154

Soil Amendments 175
Supplemental BMPs - Chemical and Biological Treatment 185
Supplemental BMPs - Filtration Devices 186
Supplemental BMPs - Hydrodynamic Devices 188

Chapter 9: Modeling Methodology and Example Design Procedure

I. Description of Generic Development Site 3
II. Summary of Stormwater Management Requirements 3
III. Format of Chapter 9 5
IV. Pre-Development Analysis 5
V. Better Site Design (BSD) Analysis 12
VI. Post-Development Analysis 17
VII. Example Design Procedure Analysis 28
VIII. References 60

Appendix A: CADD Details

I. Infiltration/Recharge Facility Cross-Section 3
II. Bioretention Facilities General Plan 4
III. Filtration/Partial Recharge Facility Cross-Section 5
IV. Infiltration/Filtration/Recharge Facility Cross-Section 6
V. Filtration Only Facility Cross-Section 7
VI. Typical Dry Swale Cross-Section 8
VII. Perimeter Sand Filter Detail 9
VIII. Surface and Filter Detail 10
IX. Underground Sand Filter 11
X. Typical Infiltration Trench Cross-Section 12
XI. Infiltration Plans and Profile 13
XII. Infiltration Subsurface Plans and Profile 14
XIII. Typical Pond Plan and Profile 15
XIV. Extended Detention Shallow Wetland Plan and Profile 16
XV. Multi-Stage Outlet Structure (Orifice example) 17
XVI. Shallow Wetland Plan and Profile 18

Appendix B: Stormwater BMPs and Plant Material Selection

I. Evaluating Environmental Stress is a Critical Pre-Planning Step to Plan Material Selection 3
II. Healthy BMPs Require Vegetated Buffers 5
III. Vegetation Operations and Maintenance 8
IV. Web Reference for Stormwater BMP Plant Material 10
V. Additional References on Plant Material Selection and Maintenance 11

Appendix C: Glossary, Symbols and Acronyms

I. Acronyms 3
II. Symbols 6
III. Glossary 8

Appendix D: Construction Inspection Checklists and Submittal Forms

I. Contacts 3
II. Submittals 5
III. Construction Inspection Checklist 33
IV. Operations & Maintenance 54

Appendix E: NWA Curve Number Derivation

I. Introduction 3
II. Modeling Methodologies Examined 3
III. Comparison of Runoff Calculation Methods 3
IV. Green-Ampt to SCS Parameter Conversion 4
V. Conclusion 5
VI. Additional Considerations 5

Appendix F: Guidance on Preparation of Construction and Maintenance Costs

I. Bioretention Cost Estimate 3
II. Infiltration Basin Cost Estimate 4
III. Stormwater Pond Cost Estimate 5
IV. Stormwater Wetland Cost Estimate 6
V. Surface Sand Filter Cost Estimate 7

Appendix G: PUD and NPDES CGP

I. NWA Planned Unit Development Overlay District 3
II. MPCA Permit 19

INVER GROVE HEIGHTS
Northwest Area

Chapter 1

Purpose and Use of the Manual

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Purpose and Use of the Manual

Chapter 1

Key Topics:	**vision and goals for the project area, location of the Northwest Area (NWA), history of the area, NWA Planned Unit Development Overlay District, this manual's relationship to the state manual, use of the manual and contact information**

Contents

I. Vision and Goal of the City of Inver Grove Heights' Northwest Area..... 3
II. Relationship between NWA Stormwater Design Manual and the Minnesota Stormwater Manual 7
III. NWA Stormwater Design Manual Organization..... 7

I. Vision and Goal of the City of Inver Grove Heights' Northwest Area

In the not too distant past, the goal of an urban drainage system was to collect and route stormwater runoff to a downstream receiving stream, lake or wetland as efficiently as possible. When it became evident that this was not a sustainable water management practice, the approach changed to the routing of water into detention ponds. Although many of these ponds were designed according to EPA's Nationwide Urban Runoff Program (NURP) criteria based on 1980s studies, they too have some deficiencies in effective treatment and management of runoff.

Stormwater managers have learned that there are better ways to treat runoff water which is to let it soak into the ground as close to its source as possible and mimic the natural hydrology of the system. This not only limits the volume and rate of runoff that occurs, it also reduces the migration of polluting material that is picked up by runoff as it flows over urban surfaces and infiltration replenishes critical ground water supplies that are used as drinking water sources.

The issue facing Inver Grove Heights is that the geology of the Northwest Area has resulted in numerous landlocked/closed basin drainage systems; that is, stormwater runoff moves to low areas that in most cases do not have outlets at normal water levels. Water flows into these basins and leaves through a combination of seepage (infiltration) into the ground and evapotranspiration.

To take advantage of the good soils and geologic conditions in the City, the City has adopted a stormwater management approach that minimizes connected impervious surfaces, increases flow path and time over pervious surfaces, and decentralizes treatment (smaller localized treatment as opposed to large-scale facility development) as a first measure of control. Once these measures have been implemented as standard practice, further treatment of excess water will occur in the numerous existing natural basins.

The approach outlined in this manual provides an ecologically friendly means to mitigate the impact that development has on the water cycle. It integrates hydrologic function into site design and conserves natural resources and open space. Specific benefits of this approach are:

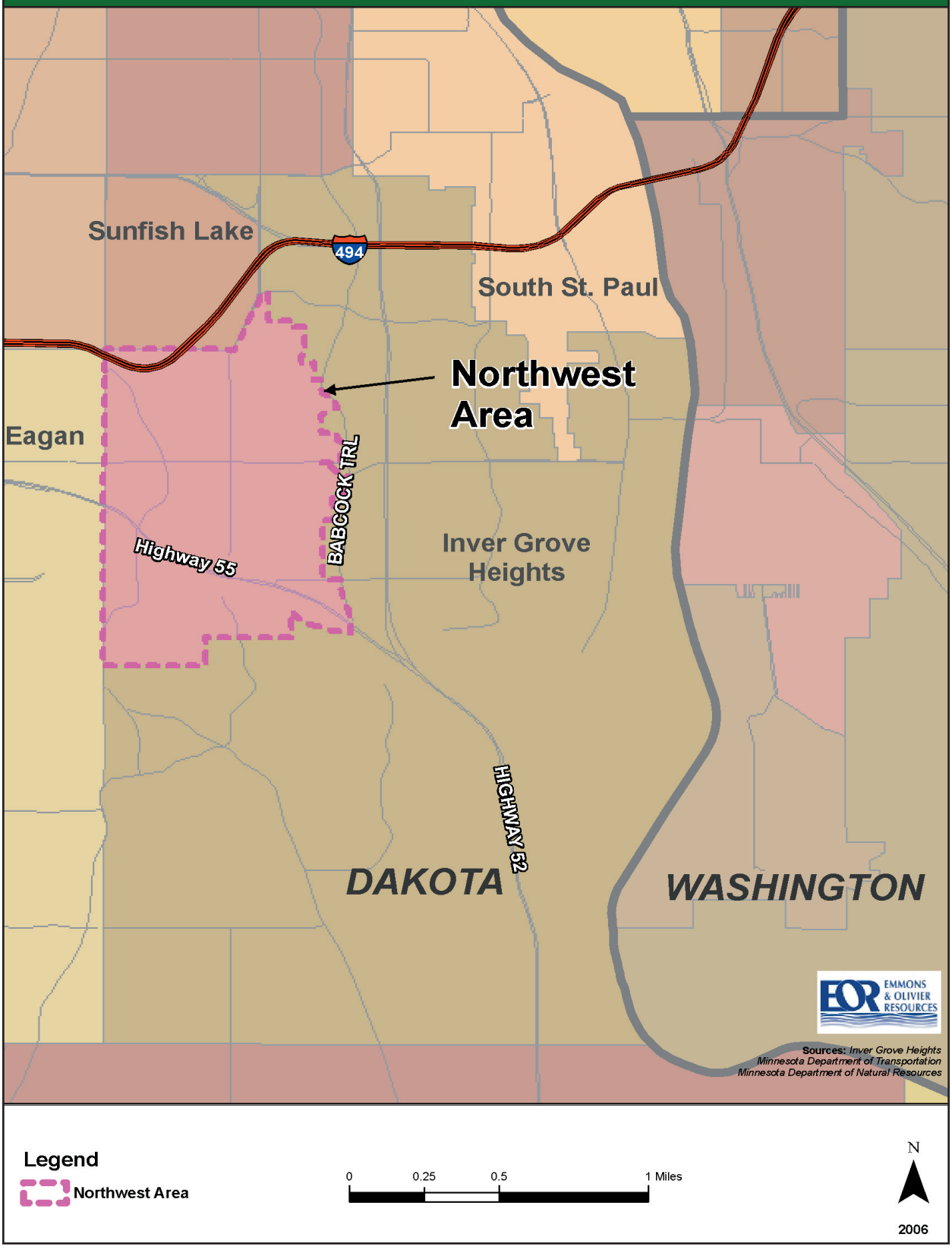
- Preservation of open space;
- Minimization of land disturbance;
- Protection of natural systems and processes, and incorporation of natural site elements into the hydrologic design;
- Customization of infrastructure to each site rather than uniform design;
- Decentralization of runoff collection;
- Management of surface water at its source; and
- Groundwater / aquifer recharge.

The list of practices included under the term "alternative" is extensive. Applications of special interest to Inver Grove Heights, because of its need to manage and reduce volume of runoff flowing to landlocked basins in the NWA, focus on infiltration.

Location

The Northwest Area (NWA) is located on 3,410 acres in the northwest portion of Inver Grove Heights, Dakota County. The location of this area is shown in Figure 1.1. The area is bounded by Interstate 494 on the north, Babcock Trail on the east, the City's boundary with Eagan on the west, and extends to an area just south of Highway 55 on the south.

Figure 1.1 Location Map of the Northwest Area, City of Inver Grove Heights



The NWA is located within two watersheds: the Lower Mississippi River Water Management Organization (LMRWMO) encompasses the eastern ¾ of the area and the Gun Club Lake Water Management Organization (GCLWMO) encompasses the western ¼ of the area (see Figure 2.4). The approximate acreage of the NWA within the LMRWMO and GCLWMO is 2,650 acres and 760 acres respectively. The NWA within the LMRWMO watershed is sub-divided into a series of 154 subwatersheds. These subwatersheds are identified in Figure 2.5. The NWA within the GCLWMO watershed is sub-divided into a series of 47 subwatersheds which is also illustrated on Figure 2.5. The LMRWMO and the GCLWMO are considered to be tributary to the Mississippi and Minnesota Rivers, respectively.

As mentioned previously, a significant portion of the NWA is landlocked. The only small areas with stormwater discharge from the NWA within the LMRWMO watershed under existing conditions occur at two locations: Basin EP-080a (Rosenberger Lake) and a small portion of Subwatershed BP-005 within the study area into MnDNR Protected Wetland 241W. Stormwater discharge from the GCLWMO watershed under existing conditions occurs at five locations: Hornbeam Lake (Q-011) to the City of Sunfish Lake and four stormwater management basins (F-025, W-002, W-004a and W-006) to the City of Eagan.

History of Stormwater Management in the NWA

In 1998, the City of Inver Grove Heights completed a Comprehensive Plan that proposed to collect and route stormwater runoff to the Mississippi River via a large regional overflow pipe system. Given the landlocked, self-sustaining nature of this relatively undeveloped area, a number of residents petitioned the City to identify and evaluate alternative methods of managing stormwater in the area.

After approximately eight years of planning and evaluating alternative stormwater management scenarios, the City of Inver Grove Heights adopted a Planned Unit Development (PUD) Overlay District for the Northwest Area (*Subdivision 39*). The purpose of the Overlay District is to regulate development in a manner consistent with the City's Comprehensive Plan while creating a cost-effective stormwater system. As stated in Subdivision 39, the Overlay District "will encourage development which provides diverse housing styles, incorporates natural features as integral elements, promotes cluster development practices which preserve significant natural features by concentrating building locations, fosters pedestrian connections and uses on-site retention of stormwater in existing landlocked basins presented in open space areas". A copy of the PUD can be found in Appendix G.

The following list of reports and events led to the development of the PUD and ultimately the NWA Stormwater Manual.

- 1998/2002 Comprehensive Plan Update
- May 2000 Northwest Area Task Force formed
- July 2000 Northwest Area Study
- September 2001 Northwest Quadrant Study
- November 2002 Northwest Quadrant Pilot Study Area Hydrologic & Hydraulic Analysis
- October 2003 Northwest Area Natural Wetland Resource Inventory
- February 2004 Northwest Quadrant Hydrologic & Hydraulic Analysis
- September 2004 – May 2005 Engineering Feasibility Study
- July 2005 Northwest Area Infrastructure Feasibility and Alternative Urban Areawide Review (AUAR)
- June 2005 public meetings
- February 2006 AUAR adopted by City Council
- August 2006 Technical Memorandum: 2005 Basin Monitoring
- August 2006 Inver Grove Heights Northwest Area Surface Water Modeling Report
- August 2006 Technical Memorandum: Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies and Cost Analysis

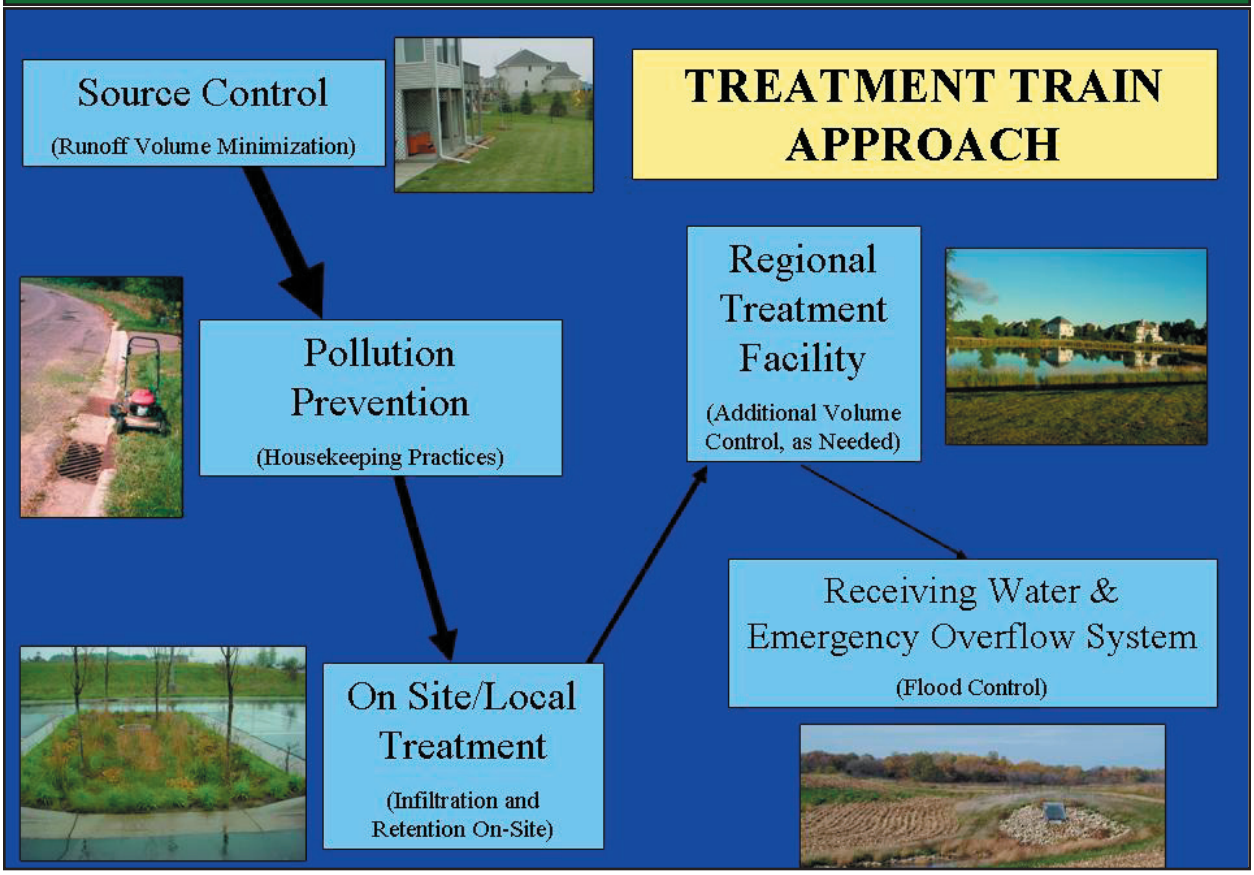
- September NWA Stormwater Manual
- 2006 Planned Unit Development (PUD) Overlay District for the Northwest Area (*Subdivision 39*)

Stormwater Management in the NWA

The City's Surface Water Management Plan for the Northwest Area applies a "treatment train" approach designed to mimic the natural hydrology of the existing system. This approach is more holistic in that its application begins at the planning stages of development and applies a number of Better Site Design techniques (BSDs) and Best Management Practices (BMPs) to minimize connected impervious surfaces, increase the flow path and time stormwater is in contact with pervious surfaces, and decentralizes treatment in local and regional infiltration areas. As Figure 2.1 illustrates, the treatment train approach begins with simple runoff volume reduction and methods that prevent pollution from accumulating on the land surface and becoming available for wash-off during a rainfall event. Additional stormwater runoff is treated in a mix of simple to complex local BMPs that treat and reduce the volume of stormwater locally before discharging to a regional stormwater management facility.

One of the main tenants of the PUD is to maintain a certain amount of open space as the NWA develops. Specifically, the PUD states that "at least 20 percent of the buildable development area within the PUD shall be preserved as additional natural area/open space". Of this natural area/open space, "50 percent may be used for passive or active recreation or the location of stormwater management facilities".

Figure 2.1 Treatment Train Approach to Stormwater Management



Source: Adapted from Minnesota Stormwater Manual 2006

Another tenant of the surface water management plan is to reduce runoff volume (to predevelopment volumes for the 5-year 24-hour rainfall event) and treat stormwater as close to its point of generation as possible before discharging to downstream water bodies or landlocked basins. A more detailed discussion of this requirement is provided in Chapter 7 of the Manual and a more detailed discussion of the treatment train approach is provided in Chapter 3 of the Manual.

II. Relationship between NWA Stormwater Design Manual and the Minnesota Stormwater Manual

The Minnesota Stormwater Manual was published in November of 2005. This manual was developed by the Minnesota Pollution Control Agency to facilitate compliance with the National Pollutant Discharge Elimination System (NPDES) permitting program. Although the material collected and presented in the Minnesota manual is very comprehensive, it is broad in scope due to the geomorphic and hydrologic variability within the state and the need to provide guidance for all possible site design constraints. For example, Inver Grove Heights need not consider design variations due to shallow granitic bedrock or lack of annual rainfall as other parts of the state would. In addition, the State Manual has more of a water quality focus than a volume control focus which is the main goal of the City's stormwater management plan. Given these considerations, there is a significant amount of cutting-edge information addressing a variety of stormwater management scenarios applicable to the NWA.

In order to facilitate compliance with the standards set forth in the PUD, the City of Inver Grove Heights developed a similar type of document using the State Manual as its foundation. To date, the City of Inver Grove Heights is the first municipality in Minnesota to adapt the State Stormwater Manual for its local stormwater management purposes. By using the State Manual as the foundation, the City of Inver Grove Heights was able to develop a cost-effective guidance tool that is tailored to the unique geomorphic and hydrologic characteristics of the NWA and the volume control standards designed to mimic the system as a whole. As a result, the NWA Stormwater Manual includes the BMP design guidance, CADD drawings, construction and maintenance checklist and costing information provided in the State Manual but also contains information addressing typical constraints in the NWA, guidance on the application of BSD techniques and a detailed example of the application of pretreatment and volume control standards to a typical development in the NWA.

III. NWA Stormwater Design Manual Organization

As development occurs in the Northwest Area, it will be necessary to ensure that the standards set forth in the PUD are met, adequate onsite volume control is provided and site-specific characteristics should be assessed to determine the most appropriate type and siting of BMPs.

This stormwater design manual provides guidance in the selection, design and construction of site specific, alternative stormwater management BMPs and is intended to be a comprehensive manual which not only summarizes the requirements and design recommendations for the NWA, but also details operation and maintenance requirements and specifications.

Developers will be responsible for coordinating with the City to ensure that the final drainage and runoff management system is designed and constructed in accordance with the stormwater management plan identified in the Comp Plan and the PUD.

Electronic copes of the Manual may be obtained on the City's web-site at http://www.ci.inver-grove-heights.mn.us/dev/nwarea.html.

If there are questions regarding the content of this Manual or the City of Inver Grove Heights' permitting program, contact:

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Inver Grove Heights, MN 55077
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(651)450-2502 (fax)
ahunting@ci.inver-grove-heights.mn.us

INVER GROVE HEIGHTS
Northwest Area

Chapter 2

Unique Features of the Northwest Area (NWA)

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Unique Features of the Northwest Area (NWA)

Chapter 2

Key Topics: general description of climate, geology, watersheds, soils, topography, wetland, and upland resources of the NWA

Contents

I. Introduction..... 3
II. Climate..... 3
III. Geology..... 4
IV. Ground Water..... 6
V. Drinking Water..... 6
VI. Watersheds..... 8
VII. Soils..... 12
VIII. Topography..... 16
IX. Wetlands..... 19
X. Lakes and Ditches..... 23
XI. Landlocked Basins..... 25
XII. Uplands..... 27
XIII. Parks and Trails..... 29
XIV. References..... 31

I. Introduction

The NWA is characterized by varied physical topography, areas of extensive tree cover, and numerous landlocked basins, some of which are wetlands. The following information characterizes the area in order to orient the Manual user to its general setting and key features. The reference section at the end of this chapter lists some additional informational resources available for the NWA, but more site specific information will be necessary for the development of individual parcels.

II. Climate

The NWA is located at the edge of the drier plains of the west and the moister woodlands of the upper Midwest. Table 2.1 depicts the annual temperature and precipitation pattern in the NWA. The NWA has cold climate conditions typical for south central Minnesota. The seasonal effects of snow, ice and spring melt can be large for both water quantity and water quality management. A more in depth discussion of cold climate considerations is conducted in Chapter 6 and cold climate design modifications for specific BMPs is discussed in Chapter 8.

Table 2.1 Climate Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average Maximum Temperature (°F)	22.5	28.7	40.6	57.5	70.2	78.4	83.0	80.8	71.6	59.5	40.9	27.2	55.1
Average Minimum Temperature (°F)	5.4	10.7	22.4	35.8	47.7	57.2	62.5	60.4	51.3	39.9	25.9	12.1	35.9
Average Total Precipitation (Inches)	0.94	0.77	1.81	2.59	3.81	4.76	4.05	4.09	3.25	2.52	1.81	0.99	31.39
Average Total Snowfall (Inches)	11.1	8.0	9.9	3.0	0.0	0.0	0.0	0.0	0.0	0.4	7.2	9.5	49.1
Average Snow Depth (Inches)	8.0	9.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.0	2.0
Average Date of First Snowfall	November 12												
Average Date of Snowmelt	March 19												

Source: MN Climatology Working Group, 2006

III. Geology

Three general types of glacial deposits are found in the project area (Figure 2.1):

- Till – Primarily sandy loam-textured, unsorted sediment.
- Ice-contact deposits – Sand and gravel. Not as prevalent as the till.
- Outwash – Sand and gravel, but more continuous and consistent than the ice-contact deposits. Occurs only in the southwest part of the project area.

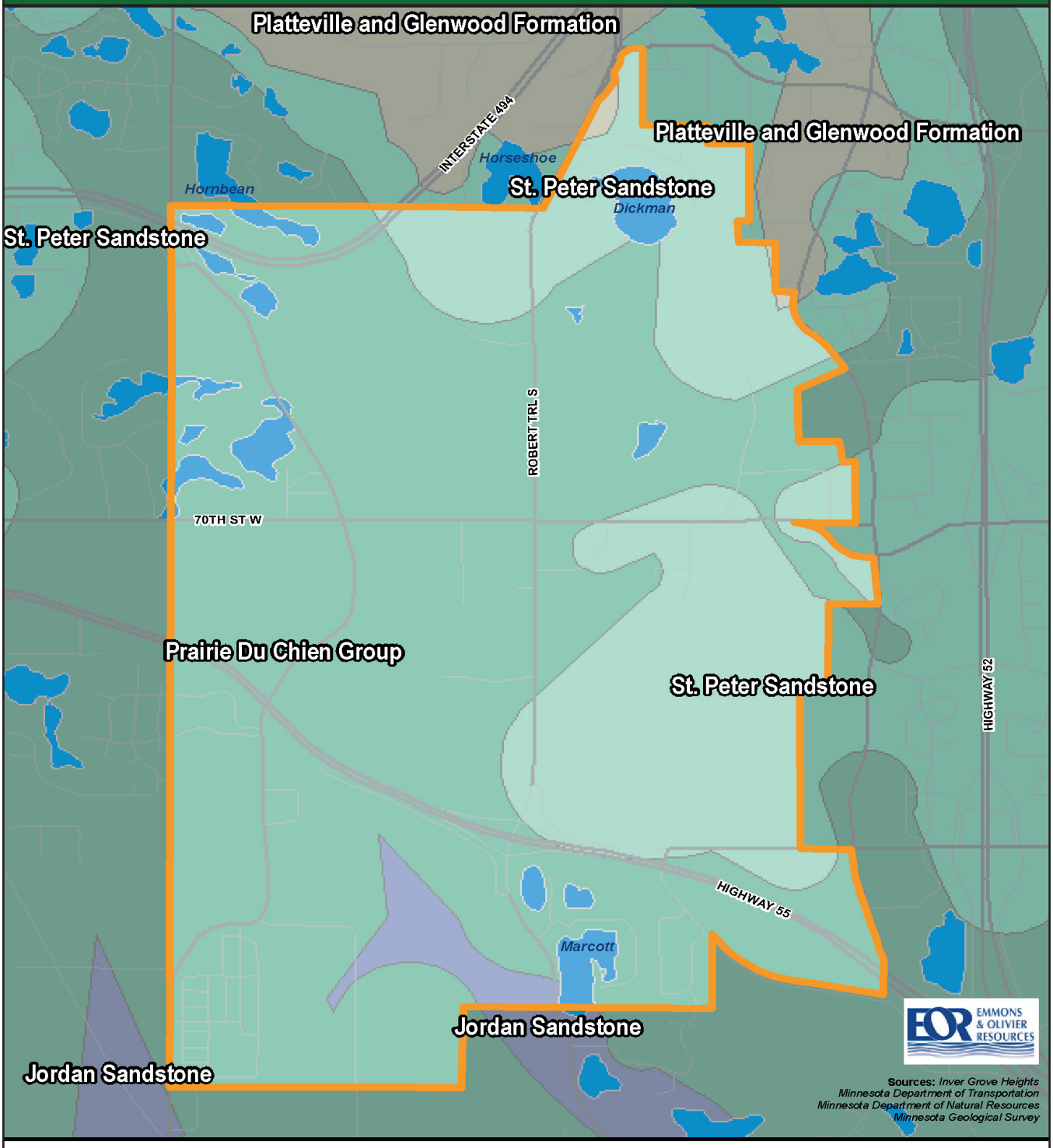
The bedrock is typical of other areas in the Twin Cities. From top to bottom, the most important bedrock formations are:

- Platteville and Glenwood Limestone/Dolomite
- St. Peter Sandstone
- Prairie du Chien Limestone/Dolomite
- Jordan Sandstone

A buried bedrock valley is mapped in the project area with branches entering it from the northwest and northeast. These branches meet and exit along the southern boundary of the project area. The bedrock valley is eroded completely through the Prairie du Chien Group and into the underlying Jordan Sandstone in the southern part of the project area. Minimum depth to bedrock within the project area is greater than 100 ft and bedrock is generally within 250 ft of the surface where the St. Peter Sandstone is present and generally greater than 200 ft where the Prairie du Chien Group is the uppermost bedrock unit.

No sinkholes, shallow limestone formations, or karst conditions are present within the project area.

Figure 2.1 Bedrock Geology Map



IV. Ground Water

The first groundwater encountered (water table) when drilling or excavating in the project area is typically in the glacial deposits. A perched water table occurs in some areas, meaning that the groundwater may not be laterally continuous and may not be hydraulically connected to lower aquifers. In addition, some areas may become seasonally saturated near the surface. As a result, it is difficult to predict the depth to groundwater at any location without a site-specific investigation. The depth to groundwater can vary from 0 to over 50 feet depending on the topography and location relative to surface water and perched aquifers.

The glacial deposits in which the water table occurs across most of the project area are not typically used for water supply. Residential and municipal wells are typically completed in the lower St. Peter Sandstone, Prairie du Chien, and Jordan bedrock aquifers. Deeper bedrock aquifers are less sensitive to pollution than the water table system.

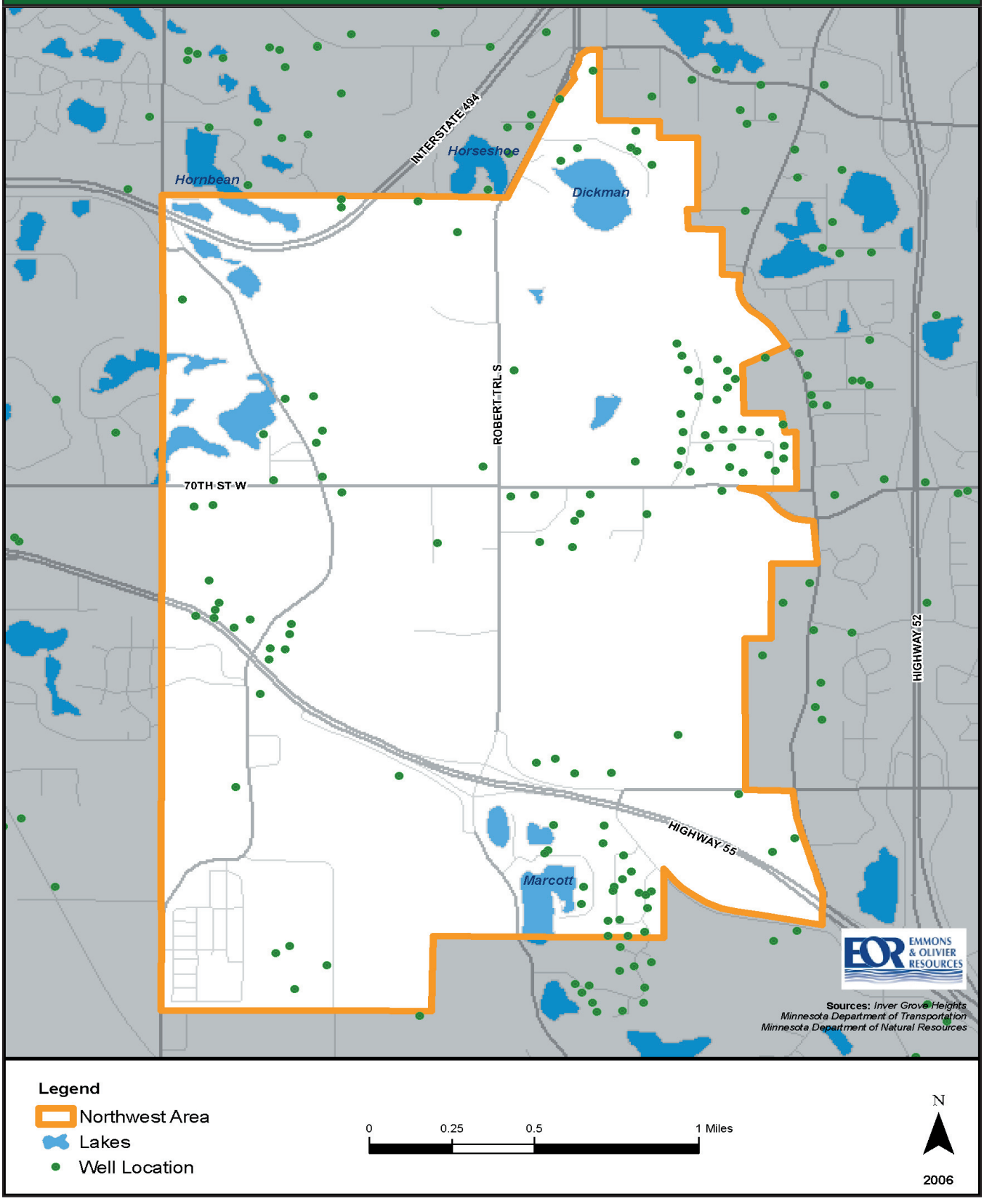
V. Drinking Water

The City of Inver Grove Heights currently operates six municipal supply wells with a total ground water appropriation of 1250 million gallons per year (2003). The NWA area will be served by expanding the existing municipal water supply system and will require additional appropriation of ground water. Five additional wells will likely be required to meet the ultimate system demand. The final number of new wells will depend on their capacities. While no municipal wells currently exist in the NWA, the city is exploring the addition of at least two wells just to the east of the NWA, on the site of the Inver Wood Golf Course.

New wells will be completed in the Jordan Sandstone portion of the Prairie du Chien-Jordan aquifer system. While the City's current wells will experience a gradual increase in pumping and additional wells will be constructed, the aquifer is expected to be able to accommodate the additional withdrawals, based on recent tests. An expansion of the water treatment facility is also planned to service the area (AUAR, 2005).

Currently, private wells service the majority of the area (Figure 2.2). Most water wells in the area are completed in buried quaternary or bedrock aquifers.

Figure 2.2 Private Well Location Map



VI. Watersheds

In the western portion of the NWA, the Board of Water and Soil Resources identifies a watershed divide between the Minnesota River drainage area and the Mississippi River drainage area (Figure 2.3). However, the NWA is characterized by its landlocked nature. Composed of numerous isolated basins, the area contains no tributary rivers or streams, and has no natural outlet to these river systems.

Administratively, the NWA is located within two watershed areas, the Lower Mississippi River Water Management Organization (LMRWMO) and the Gun Club Lake Water Management Organization (GCLWMO) (Figure 2.4). The approximate acreage within the LMRWMO is 2,650 acres and within the GCLWMO is 760 acres.

A total of 201 subwatersheds lie within the NWA area (Figure 2.5). The area within the LMRWMO can be sub-divided into a series of 154 subwatersheds and the area within the GCLWMO can be sub-divided into a series of 47 subwatersheds. Each of these subwatersheds was characterized for water quantity modeling under existing conditions, and was subsequently modeled for developed conditions in detail as part of the *Inver Grove Heights Northwest Area Surface Water Modeling Report*, August 2006.

Figure 2.3 Natural Watershed Divide Map

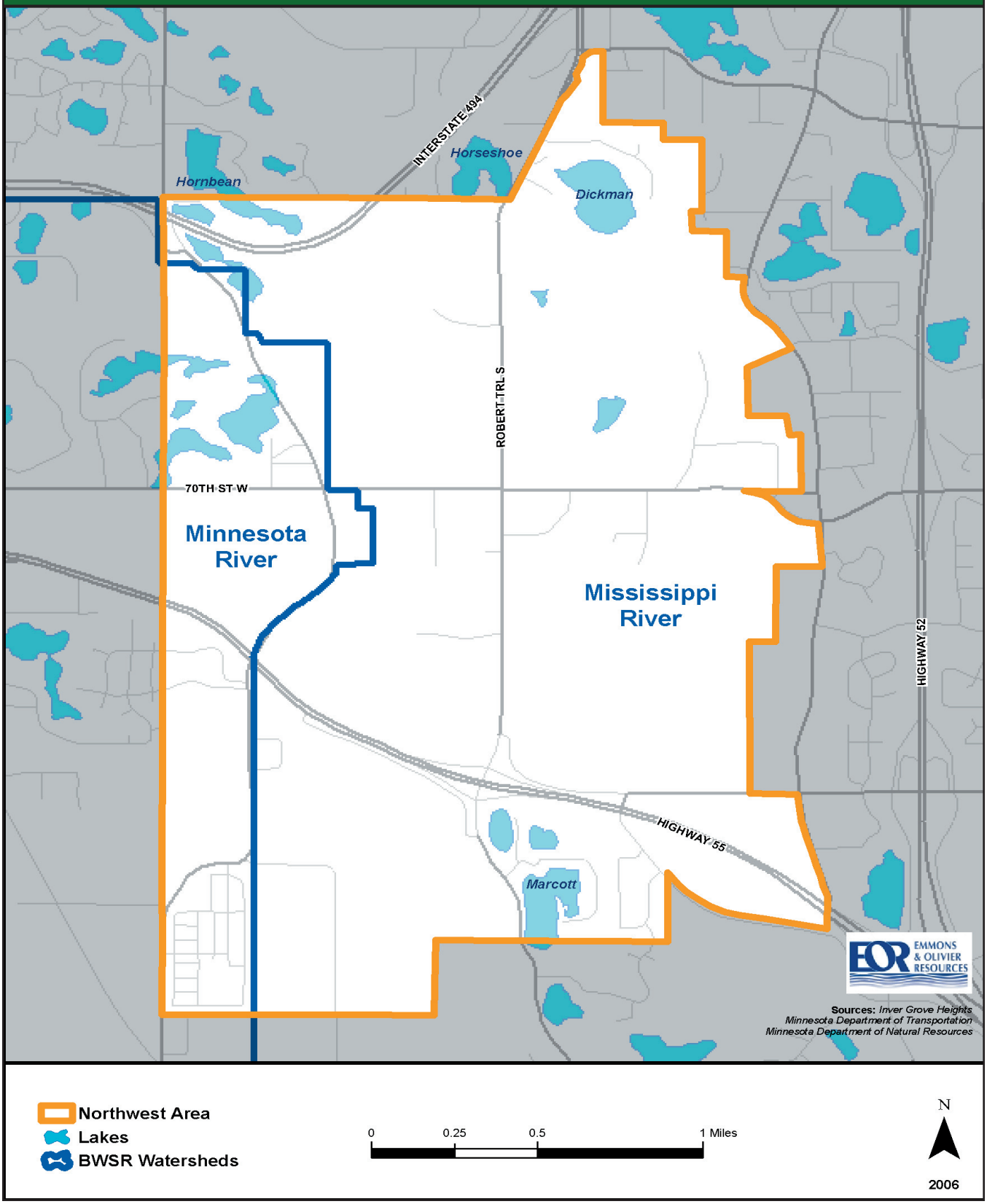


Figure 2.4 Watershed Management Organization Boundary Map

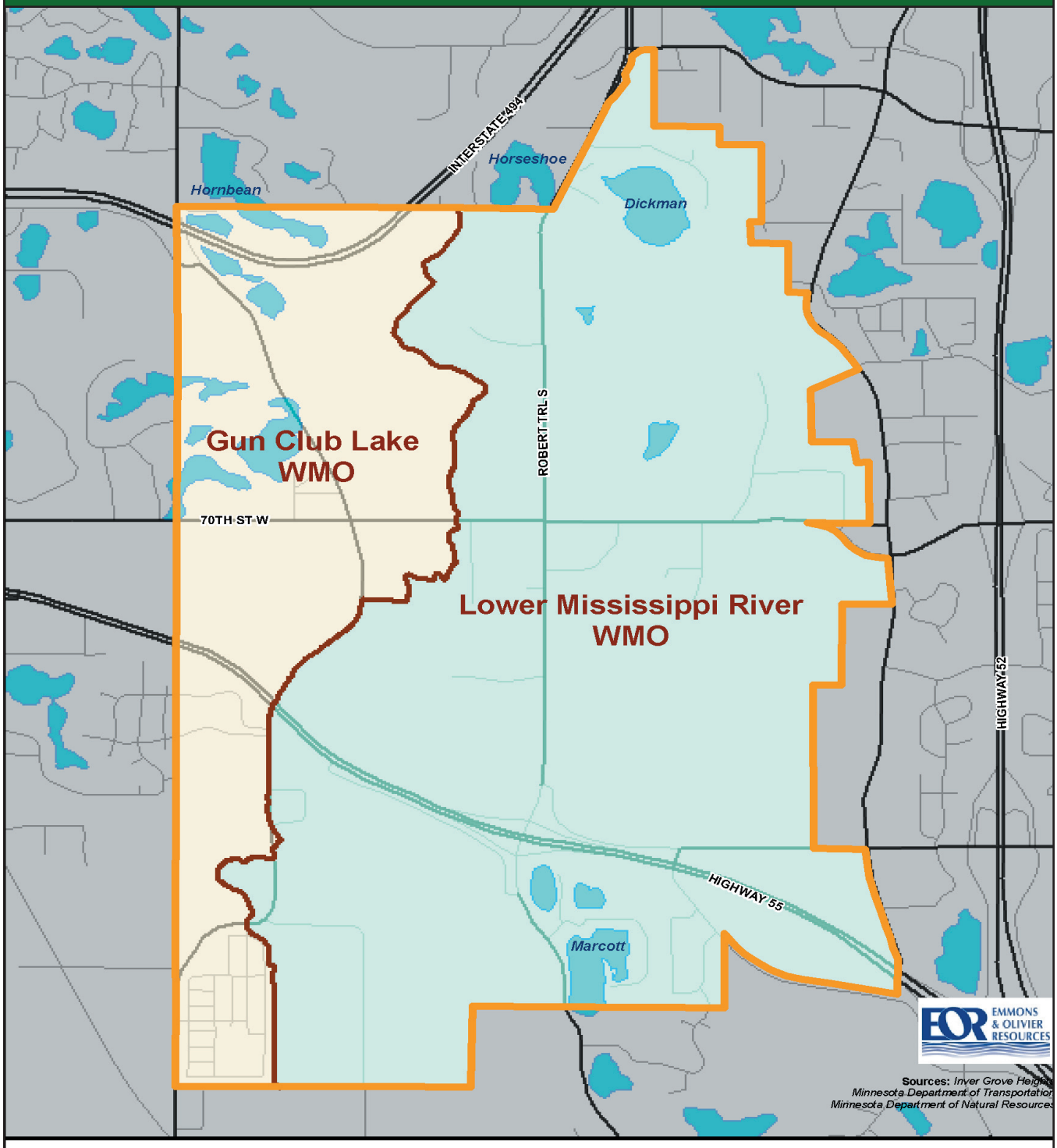
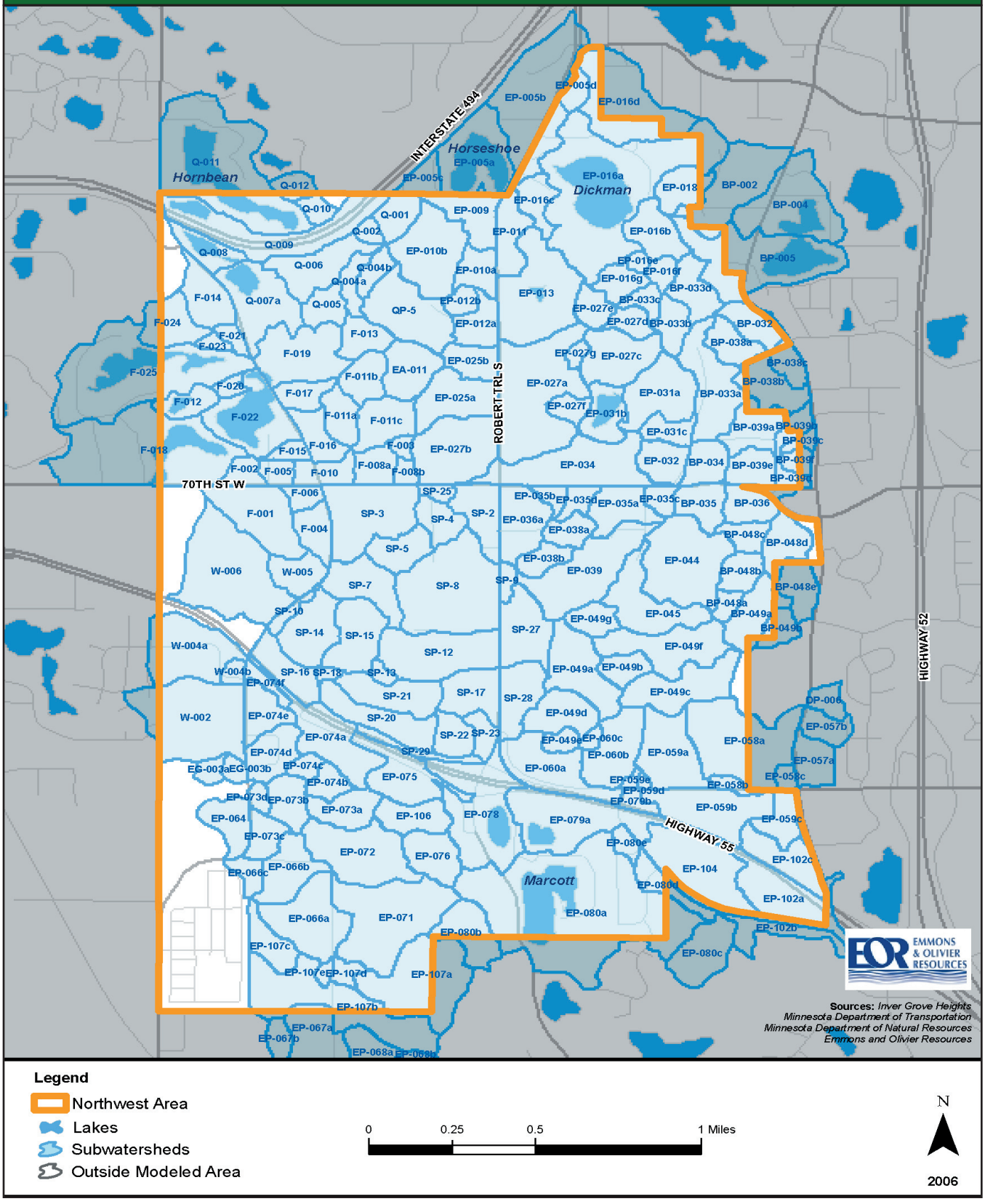


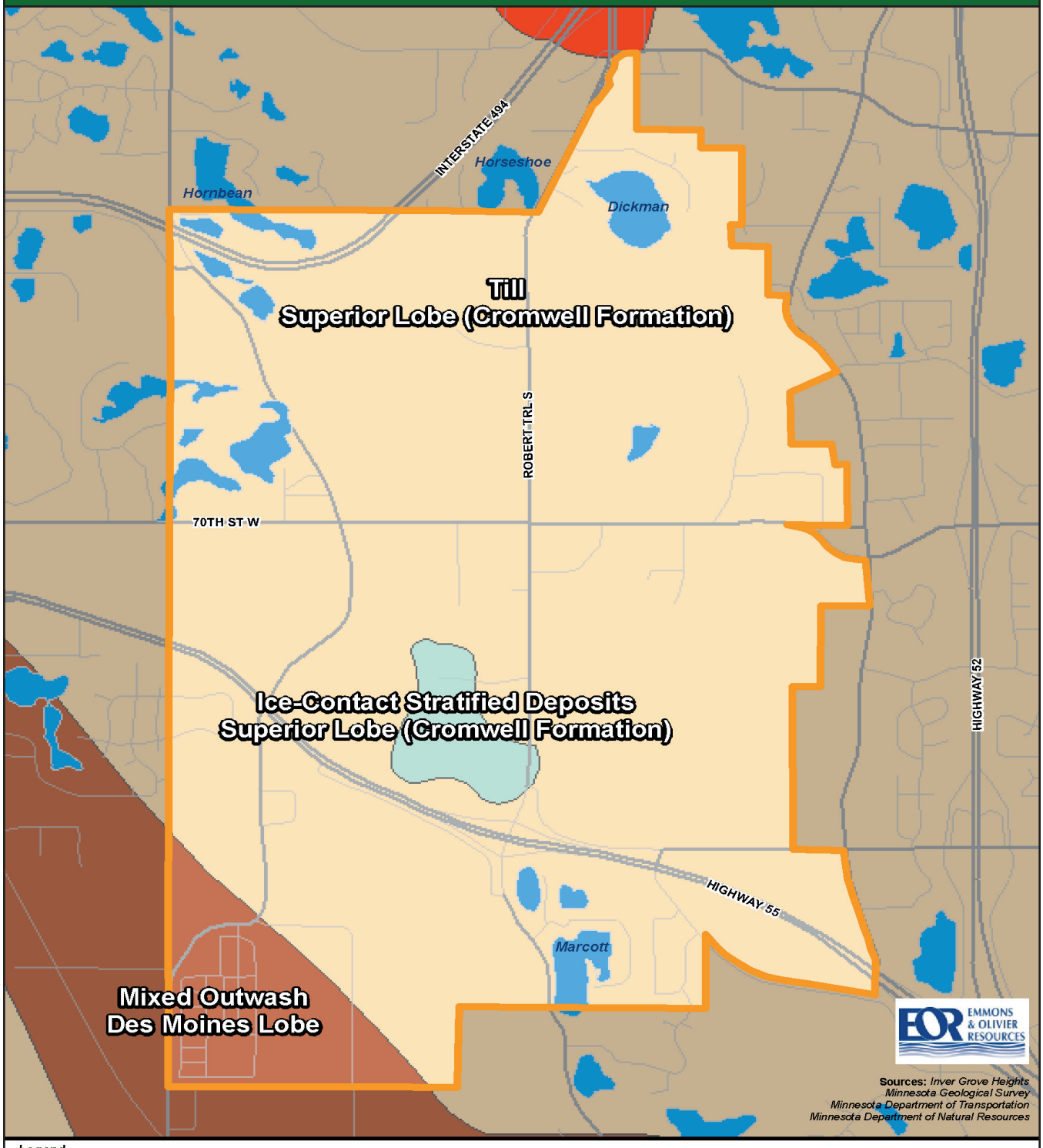
Figure 2.5 Subwatershed Map



VII. Surficial Geology and Soils

The NWA is located on the St. Croix Moraine, a geomorphic feature of hummocky terrain with glacial, fluvial and lacustrine sediments derived from the Superior Lobe (Figure 2.6). The moraine is composed primarily of unsorted sediment, mostly sandy loam-textured till. The moraine also includes deposits of stratified sand, gravelly sand and cobbly gravel with mudflow deposits and silty lake sediments. In the southwest corner of the project area sand and gravelly sand outwash of the New Ulm Formation were deposited consisting of a mixture of sediments. Much of this area was also covered by a thin mantle of loess (wind blown silt and fine sand with some clay).

Figure 2.6 Surficial Geology Map



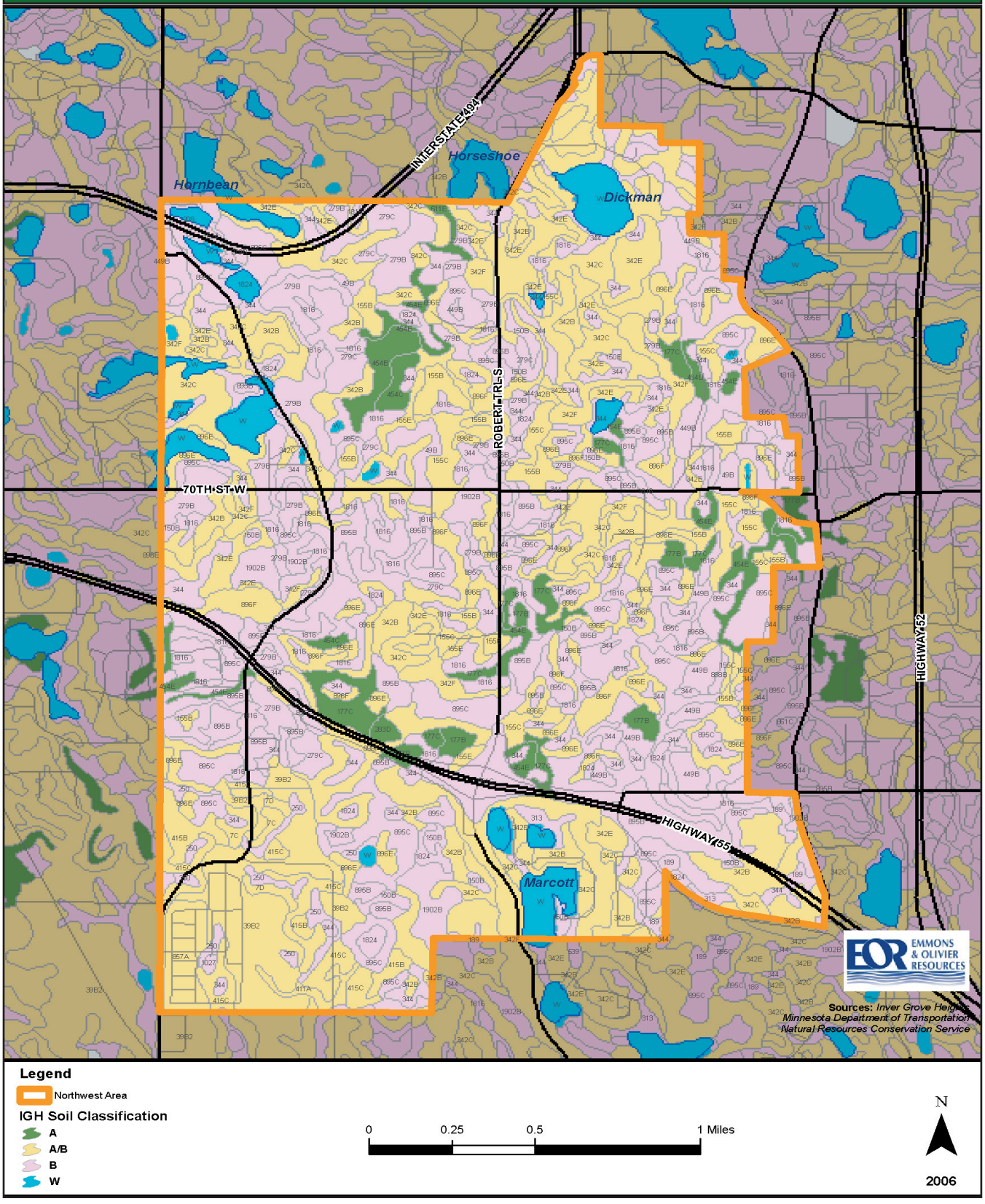
Soils are mapped in the *Soil Survey of Dakota County, Minnesota* (Hundley, 1983). Soils in the moraine belong to the Kingsley-Mahtomedi association consisting of gently sloping to very steep, well-drained and excessively drained soils. Soils in this association vary in texture from loamy sand to silty loam. Soils formed on the outwash plain belong to the Waukegan-Wadena-Hawick association of level to very steep, well drained and excessively drained soils formed in silty and loamy sediments over sandy sediments.

With development and calibration of the surface water model for the NWA, it became necessary to further subdivide hydrologic soil groups and reassign the classification for some soils to reflect actual conditions in this area (Figure 2.7). These new Inver Grove Heights Soil Classifications should be used for modeling and design purposes in sizing the stormwater management system for new developments (Table 2.2). Further detail regarding soil classifications can be found in the May 12, 2006, "Northwest Expansion Area Hydrologic & Hydraulic Analysis Update and Gun Club Lake Modeling Report".

Table 2.2 NWA Hydrologic Soil Classifications

Map Symbol	Soil Name	NWA Hydrologic Soil Type
177A,B,C	Gotham	A
283D	Plainfield	A
454B,C,E	Mahtomedi	A
611E	Hawick	A
7C,D	Hubbard	A/B
39B2	Wadena	A/B
129	Cylinder	A/B
155B,C,E	Chetek	A/B
342B,C,E,F	Kingsley	A/B
411A	Waukegan	A/B
415B,C	Kanaranzi	A/B
857A	Waukegan	A/B
858C	Chetek	A/B
889B,C,D	Wadena	A/B
	Hawick	A/B
896E,F	Kingsley	A/B
	Mahtomedi	A/B
49B	Antigo	B
94C	Terril	B
98	Colo	B
150B	Spencer	B
189	Auburndale	B
208	Kato	B
250	Kenebec	B
279B,C	Otterholt	B
313	Spillville	B
344	Quam	B
449B	Crystal Lake	B
539	Palms	B
861C	Kingsley	B
888B	Kingsley	B
895B,C	Kingsley	B
	Mahtomedi	B
	Spencer	B
1027	Udorthents	B
1029	Pits	B
1816	Kennebec Variant	B
1824	Quam	B
1902B	Jewett	B

Figure 2.7 Soils Series and NWA Soil Classification Map



VIII. Topography

Topography is extremely variable in the NWA. The area is characterized by morrainal and outwash plain creating flat areas, steep slopes, and undulating topography (Figure 2.8). The NWA is marked by landlocked basins throughout the area.

Steep slopes, which can be found throughout the area, are characterized in the PUD as those with a grade of 25% or more for a horizontal distance of 50 feet or more (Figure 2.9). Setting aside steep slope areas as open space upon new development is encouraged.

Figure 2.8 Topographic Map

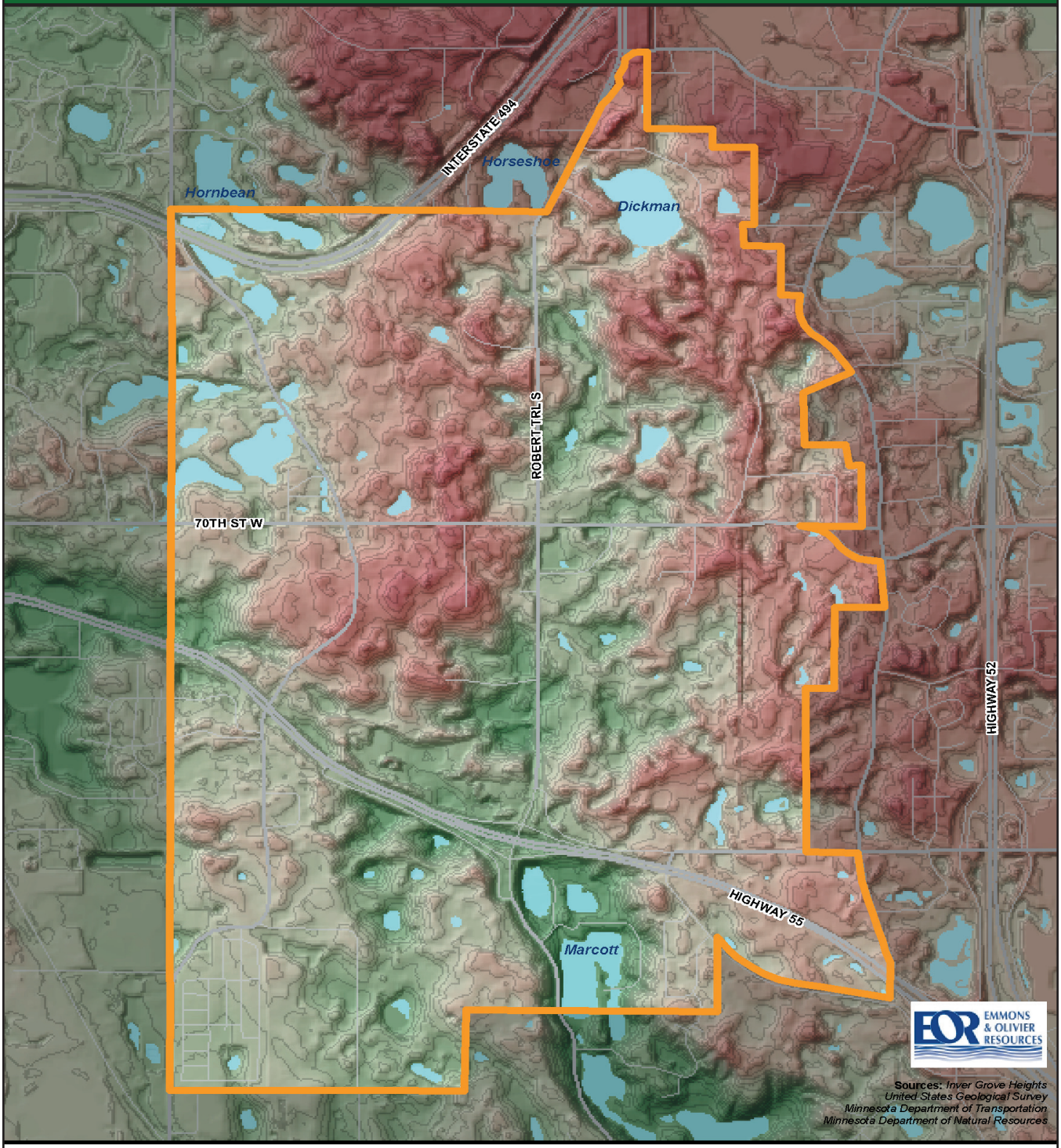
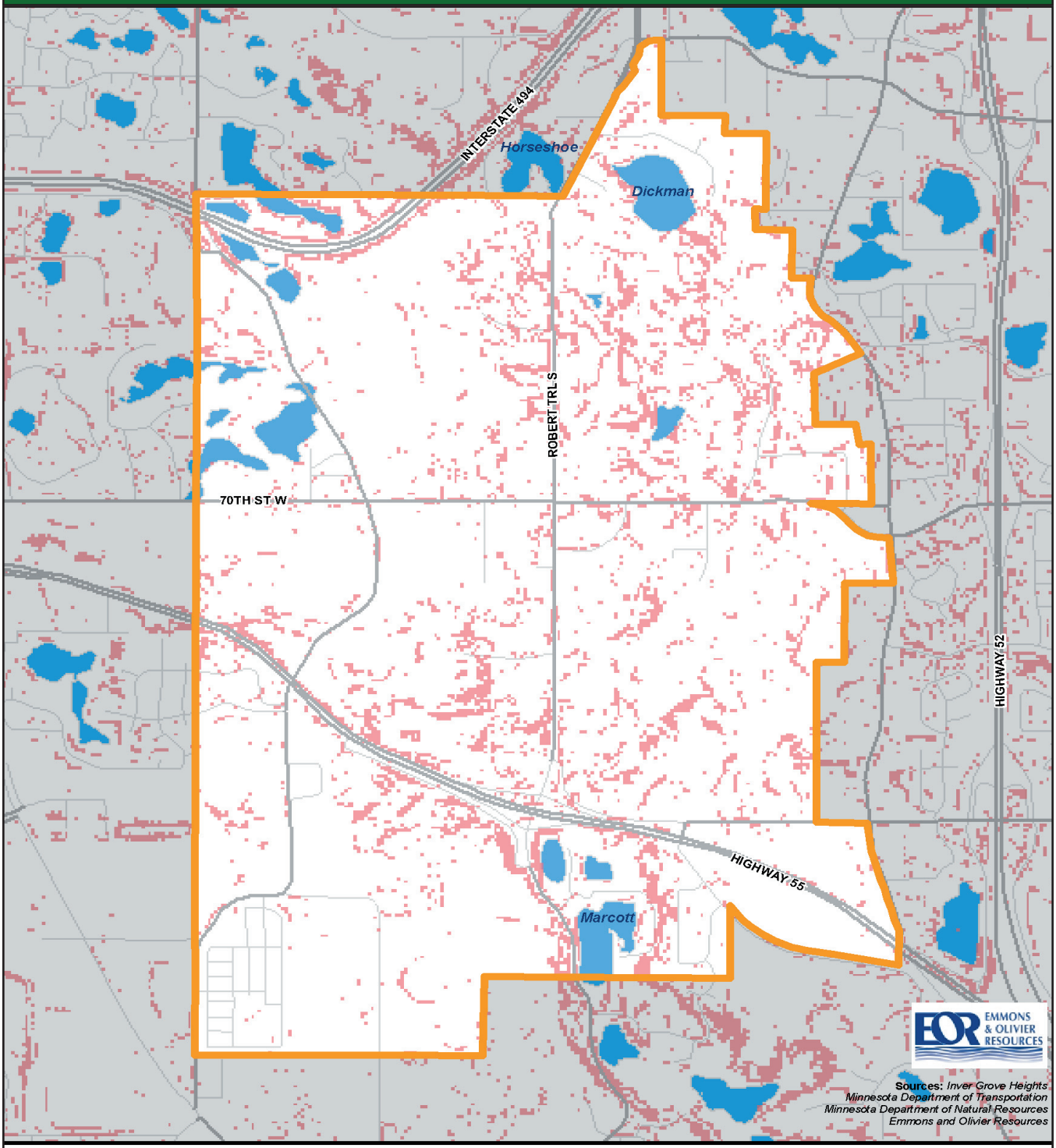


Figure 2.9 Steep Slopes Map



IX. Wetlands

Approximately 270 acres of wetland are identified in the NWA area. Wetlands were inventoried using the Minnesota Routine Assessment Methodology (MnRAM), and classified into four types based on their vegetative communities and susceptibility to stormwater impacts in the city's Natural Resources Inventory and Management Plan for the Northwest Area (BRAA, 2004). This report proposed wetland management classifications with the greatest protection begin given to the highest quality wetlands (Figure 2.10). The Wetland Management Standards adopted by the City are summarized in Table 2.3 as follows:

Table 2.3 Wetland Management Standards

Management Classification	Buffer Strip	Structural Setback from Edge of Buffer	Stormwater Quantity Required
Manage 1	60'	10'	Storm bounce—maintain HWL at or below existing conditions for 100-yr storm.
Manage 2	30'	10'	Storm bounce—maintain HWL bounce at or below existing conditions plus 0.5 ft. for 100-yr storm.
Manage 3	20'	10'	No requirement
Manage 4	15'	10'	No requirement

Source: BRAA, 2004

The most common wetland community types in the Northwest Area are wet meadow, shallow marsh, shallow open water and deep marsh. Some wetland types that are uncommon in the Metro Area, but do occur in the NWA, are Shrub Carr and Alder Thicket. Table 2.4 summarizes the wetland types and their quality rankings in the study area. Roughly two-thirds of these community types are classified as Management Classes 3 or 4. This indicates in a general sense that many of these areas are of somewhat lower quality and adversely affected by runoff, surrounding land uses and invasive species.

Table 2.4 Wetland Management Classification Summary			
Community Type	**Management Class**	**Number of Wetlands**	**Acres of Community Type**
Seasonally flooded basin	1	1	1.1
Sedge Meadow	1	3	10.7
	2	1	
	3	2	
Wet meadow	1	7	68.7
	2	8	
	3	19	
	4	20	
Alder thicket	1	1	3.5
Shrub carr	1	1	6.0
	2	1	
	3	1	
Hardwood swamp	1	4	14.8
	3	7	
	4	6	
Shallow marsh	1	8	52.4
	2	7	
	3	15	
Shallow open water	1	2	51.5
	2	2	
	3	10	
	4	10	
Source: BRAA, 2004 Deep marsh	1	6	49.5
	2	4	
	3	10	
	4	9	
Other	1	1	8.6
	4	2	
TOTAL		184	266.8

Source: BRAA, 2004

These standards, along with standards adopted in the Comprehensive Plan for water bodies, will guide wetland protection in the NWA area.

Several lakes and wetland basins in the NWA are classified as Minnesota Department of Natural Resources Public Waters and Public Waters wetland (Figure 2.11). Public waters have additional state level regulation for activities which may impact them. Additionally, the Minnesota Wetland Conservation Act also governs activities which have the potential to affect wetlands in the state.

Figure 2.10 Wetlands by Management Class Map

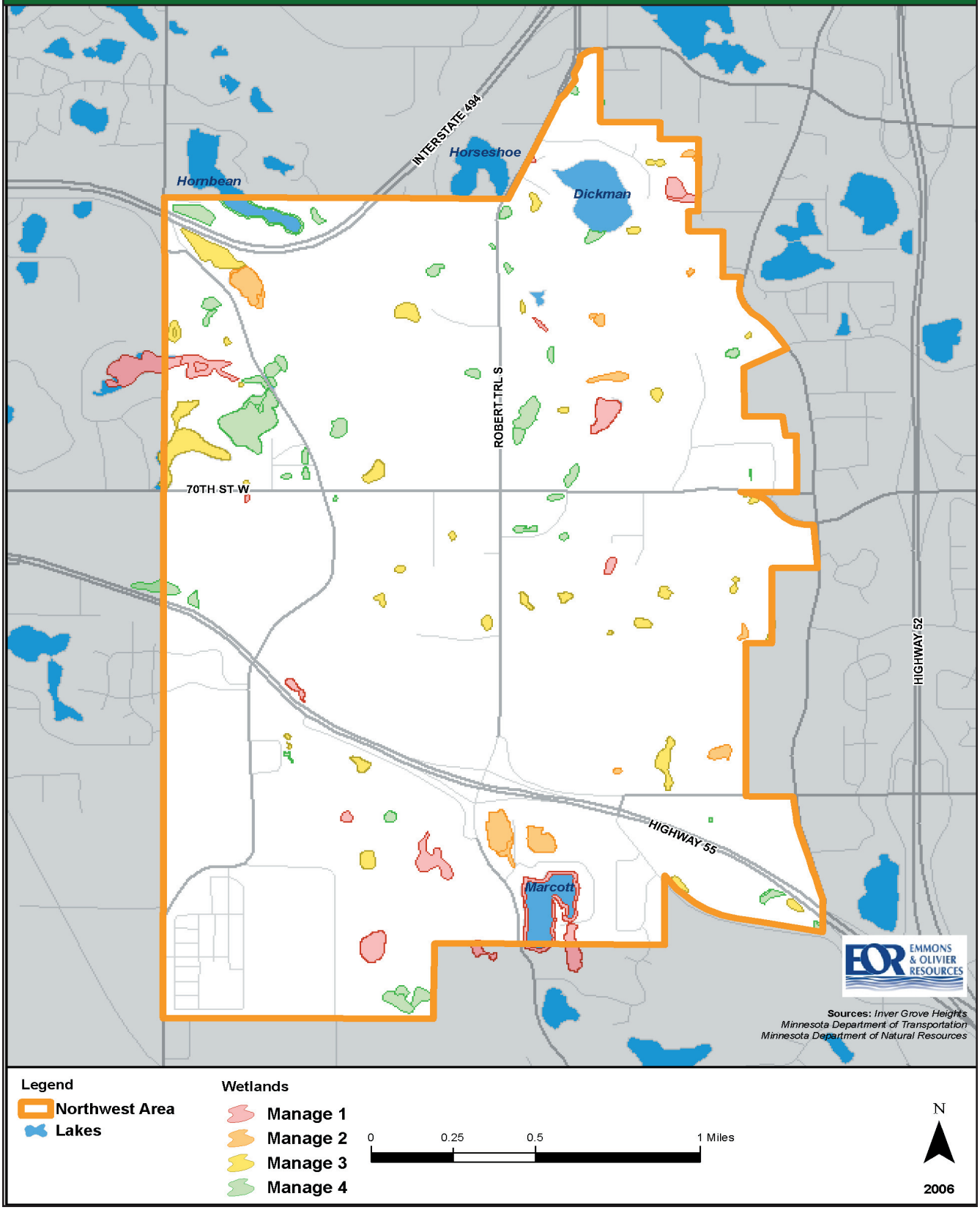
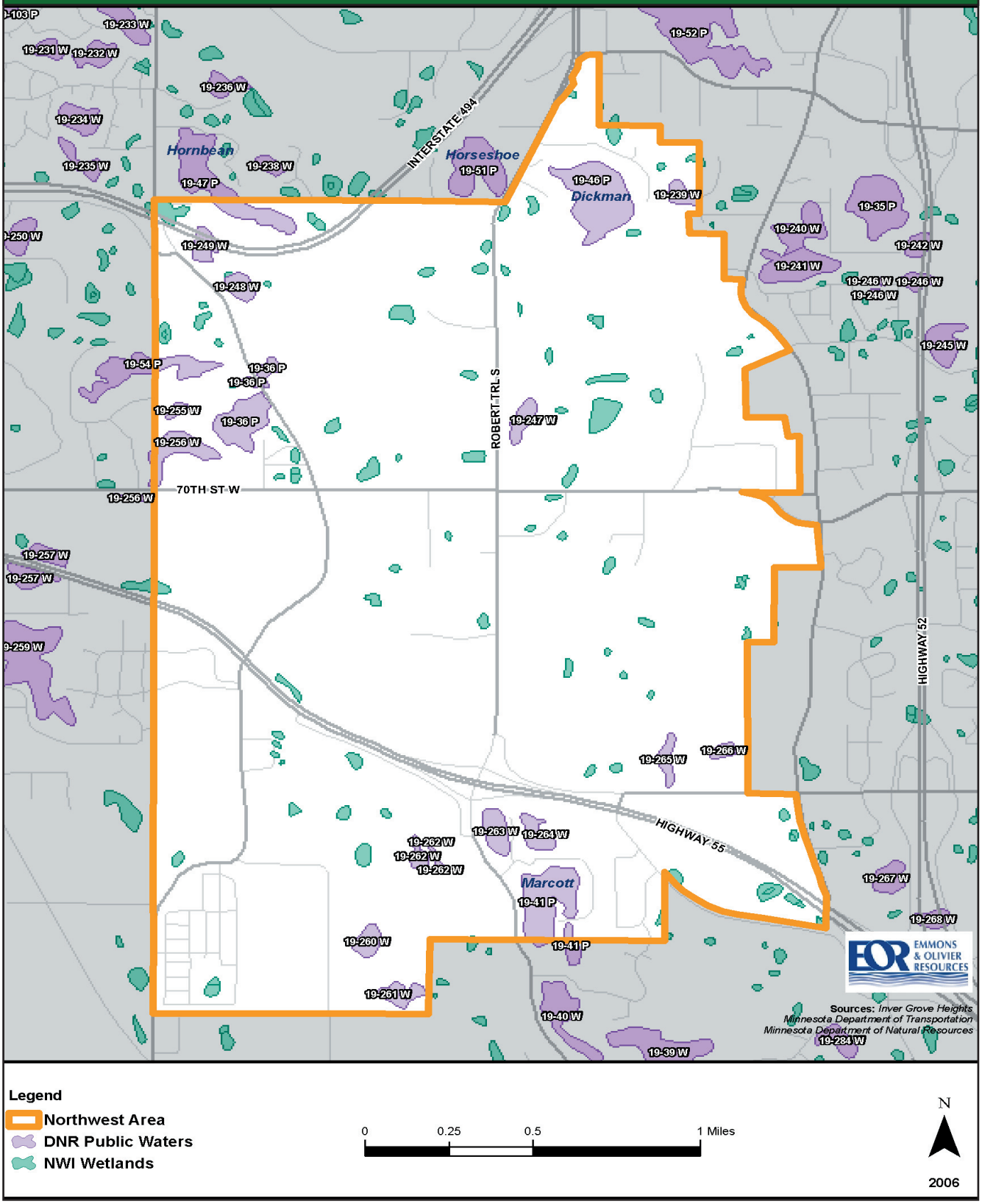


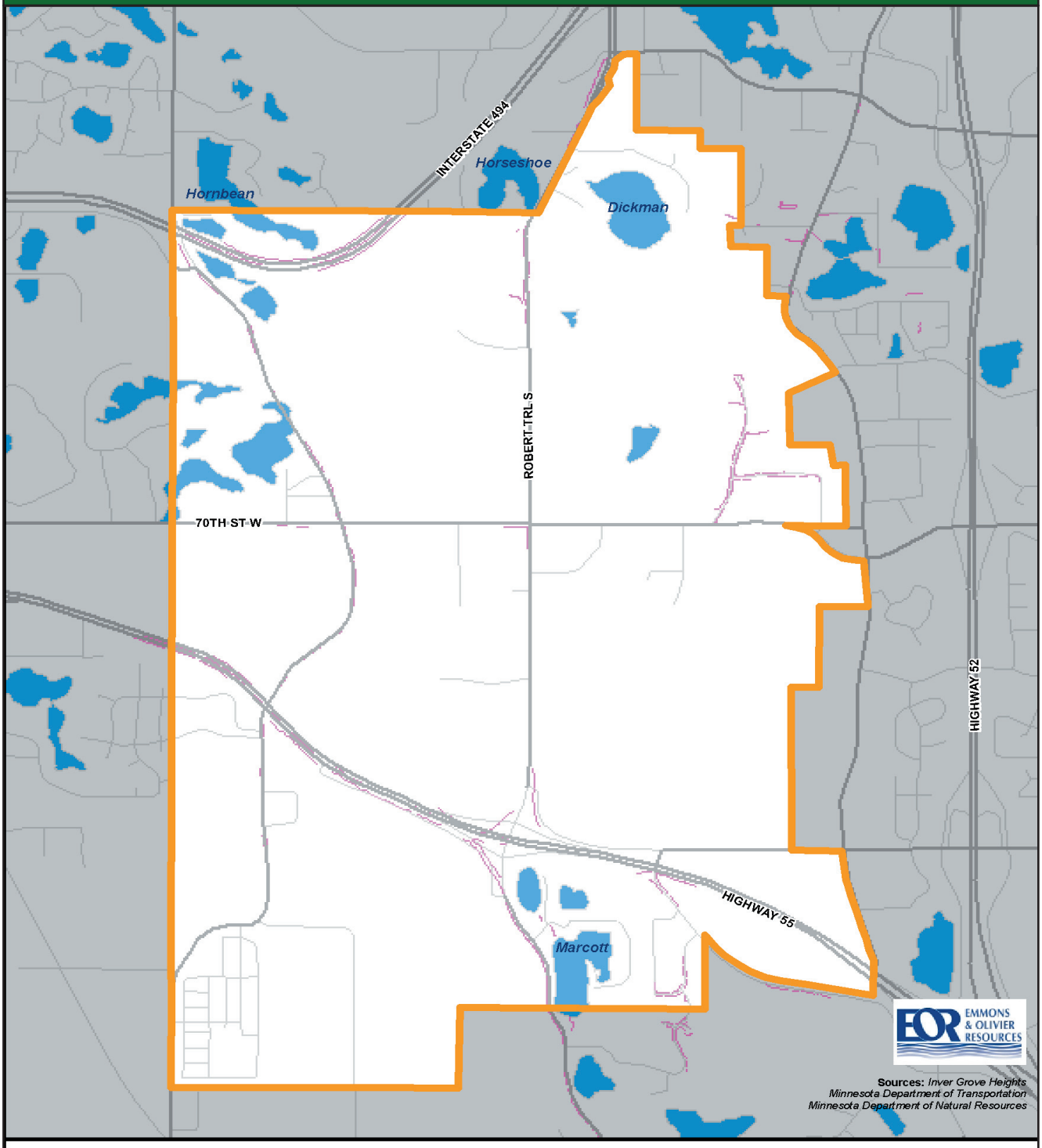
Figure 2.11 Public Waters and National Wetlands Inventory Map



X. Lakes and Ditches

The Northwest Area does not contain or drain to any MnDNR designated trout streams or Metropolitan Council priority lakes. However, a fair number of the natural basins are mapped as lakes including three of note (Dickman, Hornbean, and Marcott). Several non-jurisdictional ditches are also present in the area, mainly along roadways to act as conveyance for stormwater (Figure 2.12).

Figure 2.12 Lakes and Ditches Map



XI. Landlocked Basins

The NWA is characterized by many landlocked basins (Figure 2.13). These basins have been classified into three management categories according to their overflow potential into the regional system. Some subwatersheds are uncategorized for one or more of the following reasons:

- An existing outlet is present
- The basin is located in a golf course so the risk of flood damage is low
- The basin is located in an area that is already developed so no changes are proposed to limit new expenses for existing residents
- The area proposed to be developed has no basin

More information on these basins and the classification system can be found in the Technical Memorandum: Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies & Cost Analysis (EOR, 2006).

Categories were determined as follows in Table 2.5:

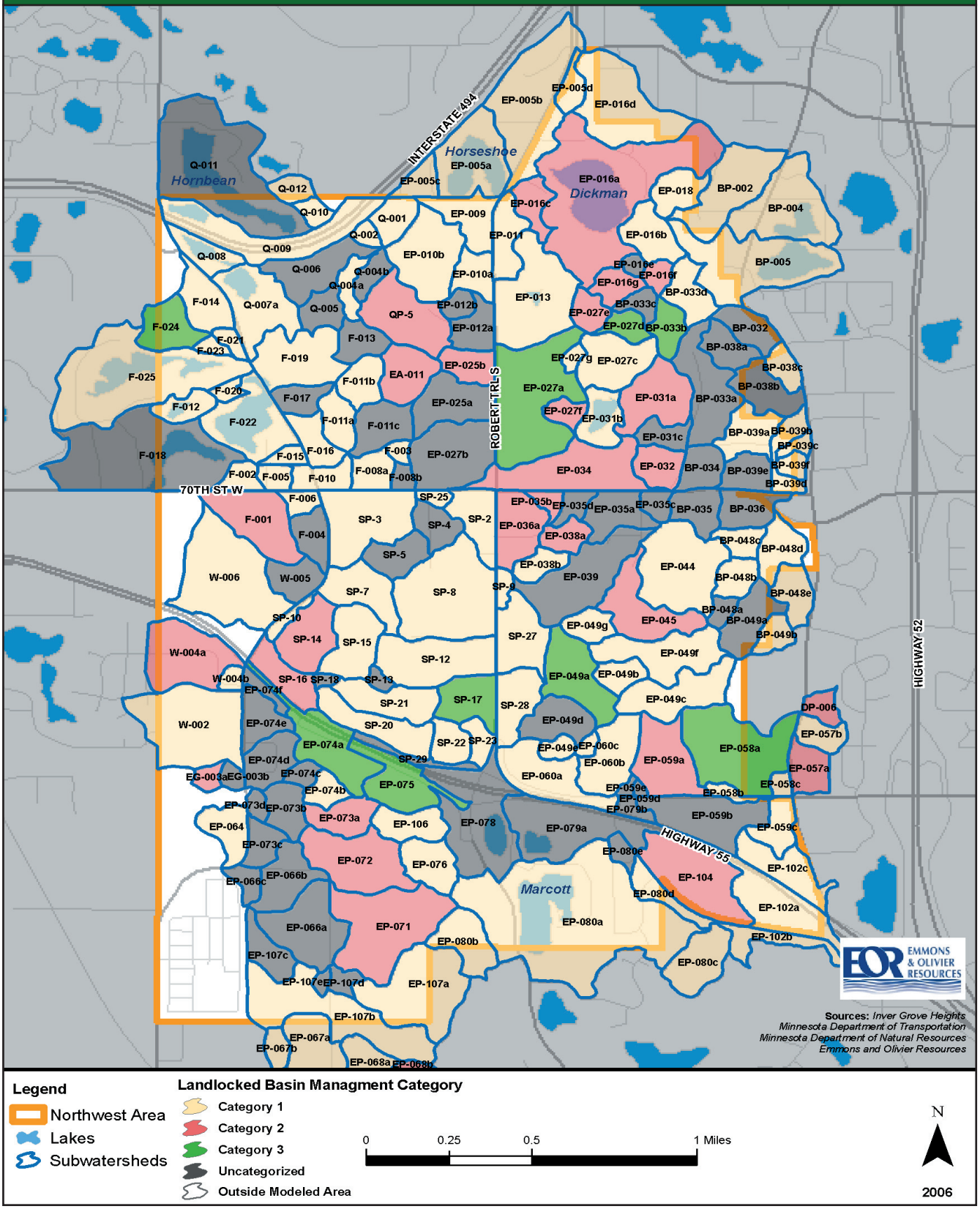
Table 2.5 Landlocked Basin Categories

Management Category	Definition*	Description
Category 1	NOF-HWL is between 0 – 6 feet	No additional infrastructure to be provided. Preserve existing natural overflow.
Category 2	NOF-HWL is between 6 – 18 feet	To ensure limitation of property damages in the event of extreme flooding, an emergency back-up outlet will be constructed for basins in this category.
Category 3	NOF-HWL is greater than 18 feet	A contingency overflow and location must be identified and an easement must be provided along the potential drainage way.

*NOF = natural overflow (elevation at which a landlocked basin would overflow)
HWL = high water level defined by critical event (as provided by City or updated by applicant's modeling results of critical event)

Source: EOR, 2006

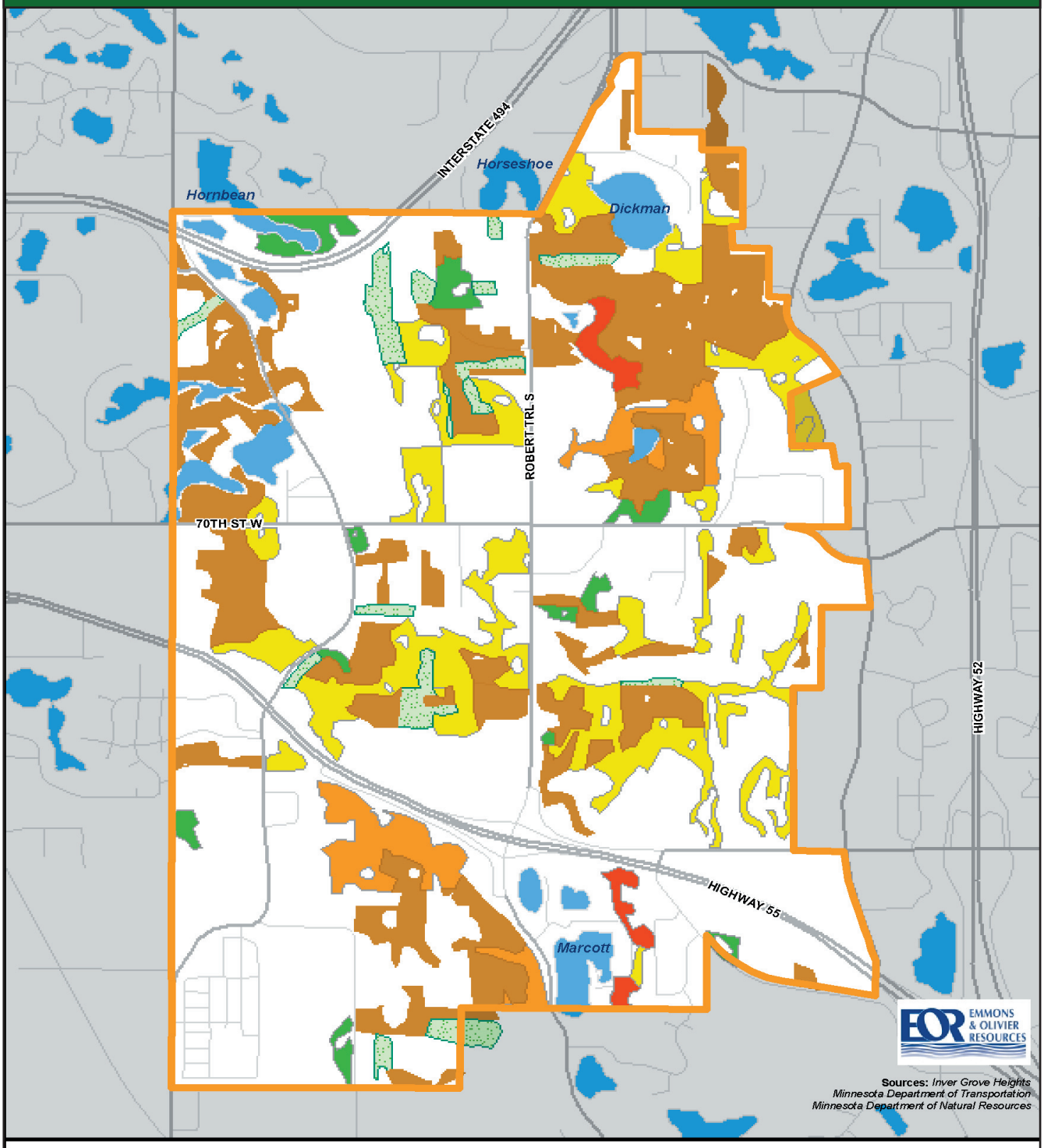
Figure 2.13 Landlocked Basin Classification Map



XII. Uplands

Upland areas of note were inventoried and divided into management classes (Figure 2.14) based upon quality (BRAA, 2004). The management standards included in that document are intended to reduce impact from development, maintain the current condition of upland natural sites and, in some cases to foster improvement of natural areas.

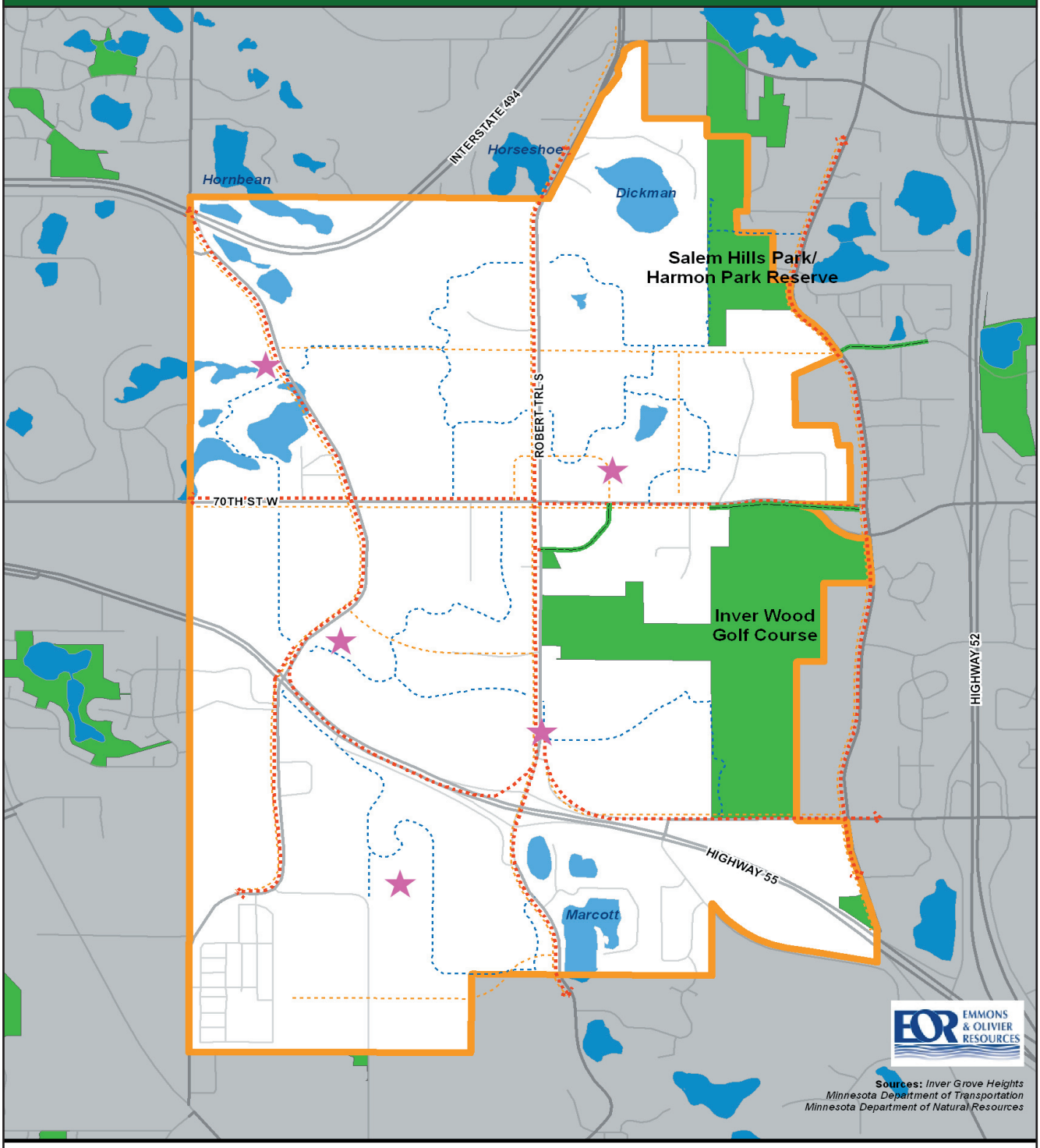
Figure 2.14 Upland Classification Map



XIII. Parks and Trails

Inver Grove Heights maintains an extensive network of parks and trails (Figure 2.16). Notable parkland in the NWA include Inver Wood Golf Course and Salem Hills Park. Several new parks and trails are envisioned by the city as the area develops.

Figure 2.15 Parks and Trails Map



XIV. References

Bonestroo, Rosene, Anderlik, and Associates. 2004. Natural Resource Inventory and Management Plan for the Northwest Expansion Area.

City of Inver Grove Heights. 2006. Northwest Area Planned Unit Development (Subd. 39).

City of Inver Grove Heights. 2005. Inver Grove Heights Northwest Expansion Area Alternative Urban Areawide Review (AUAR).

Emmons and Olivier Resources, Inc. 2006. Inver Grove Heights Northwest Area Surface Water Modeling Report.

Emmons and Olivier Resources, Inc. 2006. Northwest Expansion Area Hydrologic & Hydraulic Analysis Update and Gun Club Lake Modeling Report.

Emmons and Olivier Resources, Inc. 2006. Technical Memorandum: Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies & Cost Analysis.

Hoisington Koegler Group Inc. 1998. 2020 Inver Grove Heights Comprehensive Plan.

Hundley, S.J. 1983. The Soil Survey of Dakota County, Minnesota.

Minnesota Climatology Working Group Website. 2006. Minnesota Department of Natural Resources Division of Waters and University of Minnesota Department of Soil, Water, and Climate. http://climate.umn.edu/

INVER GROVE HEIGHTS
Northwest Area

Chapter 3

Integrating Stormwater Management Into Site Design

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Integrating Stormwater Management Into Site Design

Chapter 3

Key Topics:	**definition of stormwater, effects of development on stormwater movement, physical and water quality impacts due to increased stormwater runoff, definition of integrated stormwater management, general stormwater management principles, treatment train approach, definition of 'best management practice', definition of 'better site design'**

Contents

I. What is Stormwater?..... 3
II. Integrated Stormwater Management..... 6
III. Integrated Stormwater Management Process..... 9
IV. Link to Better Site Design..... 14
V. References..... 15

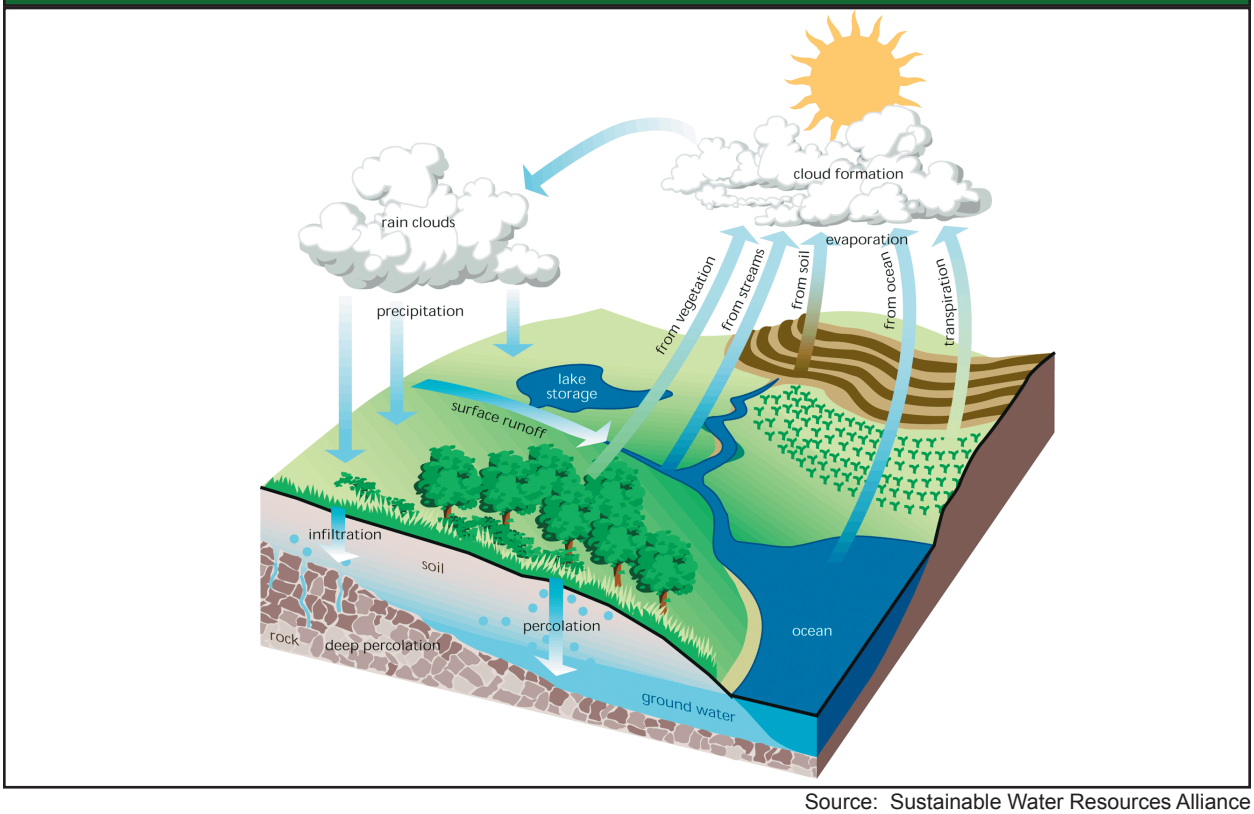
I. What is Stormwater?

Stormwater and stormwater runoff are all-inclusive terms that refer to any of the water running off of the land's surface after a rainfall or snowmelt event. Stormwater is a natural part of the hydrologic cycle, but the effects of development have a profound effect on the way that stormwater moves off of the land.

Hydrologic Cycle

The hydrologic cycle (Figure 3.1) is a representation of the distribution and movement of water between the earth's surface, subsurface, and atmosphere. Water travels from the atmosphere to the land surface in the form of precipitation. Eventually, it travels to surface water bodies through diffuse overland flow, point discharge, or as ground water flow. Water that seeps into the ground eventually replenishes ground water aquifers and surface waters such as lakes, streams, and the oceans. Ground water recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water is returned to the atmosphere through evaporation and transpiration to complete the cycle.

Figure 3.1 Hydrologic Cycle

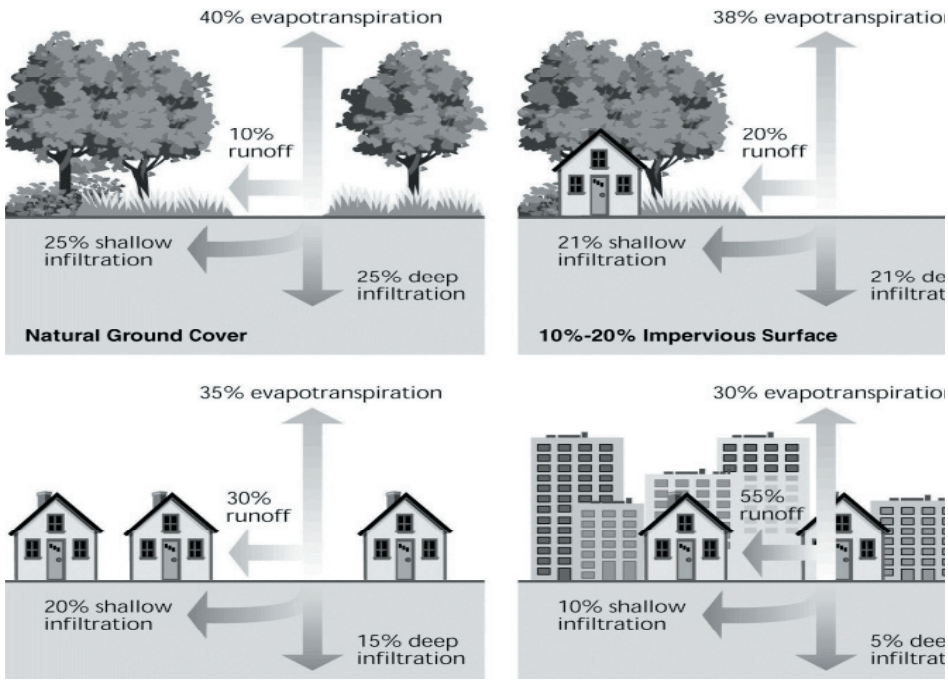


Source: Sustainable Water Resources Alliance

Effects of Development

Prior to development, stormwater runoff is a small component of the annual water balance. An increases in development alters the land cover and the balance of the water cycle changes, resulting in more surface runoff from impervious surfaces and less infiltration into the soil. Figure 3.2 shows how the relative percentages of water soaking into the ground change once development begins.

Figure 3.2 Hydrologic Effect of Imperviousness



Source: Federal Interagency Stream Restoration Work Group, 2000

The changes in the landscape that occur during the transition from rural and open space to urbanized land use have a profound effect on the movement of water off of the land and the hydrology of the local system and landscape. What used to be a small portion of runoff from a rainfall or snowmelt event becomes a major source of rapid runoff volume. This rapid runoff has enough energy to rapidly erode soils and transport particles to receiving water bodies where sedimentation can become a problem. In addition, when infiltration is reduced or eliminated, reduced volumes of ground water are available to ground water dependent resources and deeper ground water aquifer units receive less recharge.

Effects on Downstream Resources

Development within a watershed has a number of direct impacts on downstream resources, including extreme water level fluctuation, degradation of aquatic habitat, and changes to water flow, power, behavior and timing.

Development alters the hydrology of watersheds by disrupting the natural water cycle. Notable responses include:

- *Increased Runoff Volumes* – Land surface changes can dramatically increase the total volume of runoff generated in a developed watershed.
- *Increased Peak Runoff Discharges* – Increased peak discharges for a developed watershed can be two to five times higher than those for an undisturbed watershed.
- *Greater Runoff Velocities* – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- *Shorter Times of Concentration* – As runoff velocities increase, it takes less time for water to run off the land and reach a wetland or water body.

► *Reduced Ground Water Recharge* – Reduced infiltration of stormwater runoff reduces the amount of rainfall recharging ground water aquifers.

Water Quality Impacts

Quantity is not the only problem resulting from changing runoff patterns. As the changes mentioned previously occur, more water flows off of urban surfaces and is delivered downstream faster. The increased activity on these surfaces means that more polluting material is also available. Stormwater that washes over these new urban surfaces picks up a significant amount of the material laying upon them. The sediment from construction erosion, the oil, grease, and metals from many automobiles, the fertilizer and pesticides from lawns, and many more new pollutants that were not previously present all combine to adversely impact downstream resources. Table 3.1 lists many pollutants of concern and some sources of these pollutants.

Table 3.1. Nonpoint Sources and Associated Pollutants

Pollution Sources	Pollutants of Concern*
Agriculture, parks, lawn and garden maintenance	Phosphorus, nitrogen, fertilizers/pesticides, organic debris, oxygen demand
Air pollution	Organic pollutants (such as PAHs, pesticides, PCBs, phenols), heavy metals, nitrogen and sulfur oxides, hydrocarbons
Animal waste and litter	Bacteria/virus, phosphorus, nitrogen
Construction activity	Sediment, phosphorus, nitrogen, debris, sanitary waste
Illicit connections to storm sewers or improper maintenance of septic systems, sanitary services, roof/sump drains or industrial process water	Bacteria/virus, phosphorus, nitrogen, excess water, heavy metals
Improper disposal of household hazardous wastes	Any household material deemed “hazardous”
Industrial and commercial activities (loading and unloading, raw material and by-product storage, vehicle maintenance and spills)	Any raw material exposed to runoff
Municipal maintenance activities (road repair, salting, dust control, etc.)	Sediment, hydrocarbons, salt
Residential driveway and parking area runoff	Salt, PAHs, hydrocarbons, temperature (increased)
Vehicular traffic including parking lots, roadways and traffic spills	Heavy metals (such as lead, zinc, copper, cadmium, and mercury), hydrocarbons (such as oil and grease, gasoline, cleaning solvents), salt (Na and Cl), sediment
* Representative list only; many additional pollutants can be associated with most of the activities listed	

Source: Adapted from *The Stormwater Pollution Prevention Handbook*, Conservation Toronto and Region, 2001

Pollutant Impacts

The impacts of the various pollutants listed in Table 3.1 are felt to varying levels. It is important to recognize that the hydrologic balance of most receiving waters depends on this runoff water. Simply diverting all of

the flow around a water body might help reduce a pollutant load, but it could also cause the water body to dry up.

The water quality impacts from urban runoff vary depending upon the quality and quantity of the stormwater and the natural ability of the receiving water to absorb or accommodate certain pollutants without adverse effects (Conservation Toronto and Region, 2001). Depending on the chemical, biological and physical character of the water body, this assimilative capacity can be quite different and tolerance to pollutants may vary greatly. Some water bodies are inherently more sensitive to types or classes of pollutants than others. Due to its landlocked nature, this is particularly true in the NWA. As part of the Natural Resource Inventory and Management Plan for the Northwest Expansion Area (BRAA, 2004) done in the city, four management classes were set up for wetlands, with the greatest protections being given to the highest quality wetlands. For a map and wetland management standards, see Chapter 2 (insert link to Table 2.3)

Since there is a major focus on infiltration as a best management practice in the NWA, careful thought as to the potential pollutant impacts to ground water must be given when designing and locating the system. Specific pollutants of concern include such things as nitrogen, pesticides, salts, heavy metals, pathogens and other organic compounds. The pollutant impact on ground water depends upon a number of factors including: the concentration of the pollutant in the stormwater, the nature of the soil (i.e.. sandy vs. clayey), separation distance from ground water, and the organic materials present. Risk goes up as the concentration of the pollutant increases, the soils become sandier, separation distances to ground water decrease or organic materials in the soil decrease. With the exception of chlorides and some pathogens which can readily move through the soil column and into ground water, the risk for impacts to ground water in the NWA is low with proper pre-treatment and soil column separation distance from the water table. Risks are typically lowest for residential land uses since concentrations of pollutants tend to be lowest in these areas too. Careful thought should be given when applying infiltration practices in commercial or industrial areas or adjacent to heavily used roads or parking areas. For more specific design considerations, see Chapter 8 (insert link to infiltration guidance).

II. Integrated Stormwater Management

Integrated stormwater management is a comprehensive approach to stormwater management. It is a proactive method that can be used to evaluate the factors that affect precipitation as it moves through the hydrologic cycle, while at the same time accommodating the land development activities that come with population growth. The process begins with reducing the initial generation of excess runoff and then focuses on ways to control runoff rates and volumes, preserve water quality and promote ground water recharge in a logical way using the simplest techniques possible to achieve the desired management outcome. Evaluating the system in this way helps to avoid inadvertent mistakes that could eventually harm a resource.

Ground Water/Surface Water Interaction

Integrated stormwater management often takes advantage of the interaction that takes place between ground water and surface water. For example, the slow infiltration and movement of surface water into the shallow ground water system results in both peak and volume reduction, filtration through cleansing soil, and ground water replenishment. Although stormwater management is often interpreted as a surface water program, many of the BMPs suggested for the NWA rely on the ground water system to make them effective. Infiltration BMPs, for example, rely on the soil's capacity to soak water up and transmit it downward away from the practice. By recognizing this innate ability of the landscape, stormwater designers can maximize opportunities to enhance infiltration on-site to meet treatment goals in an efficient and cost effective way.

However, there must be caution used when utilizing a system that has the potential to affect ground water resources. For example, although soil adsorption is an effective scavenger of some soluble pollutants, one could argue that the introduction of runoff into any system that discharges to the ground is merely trading

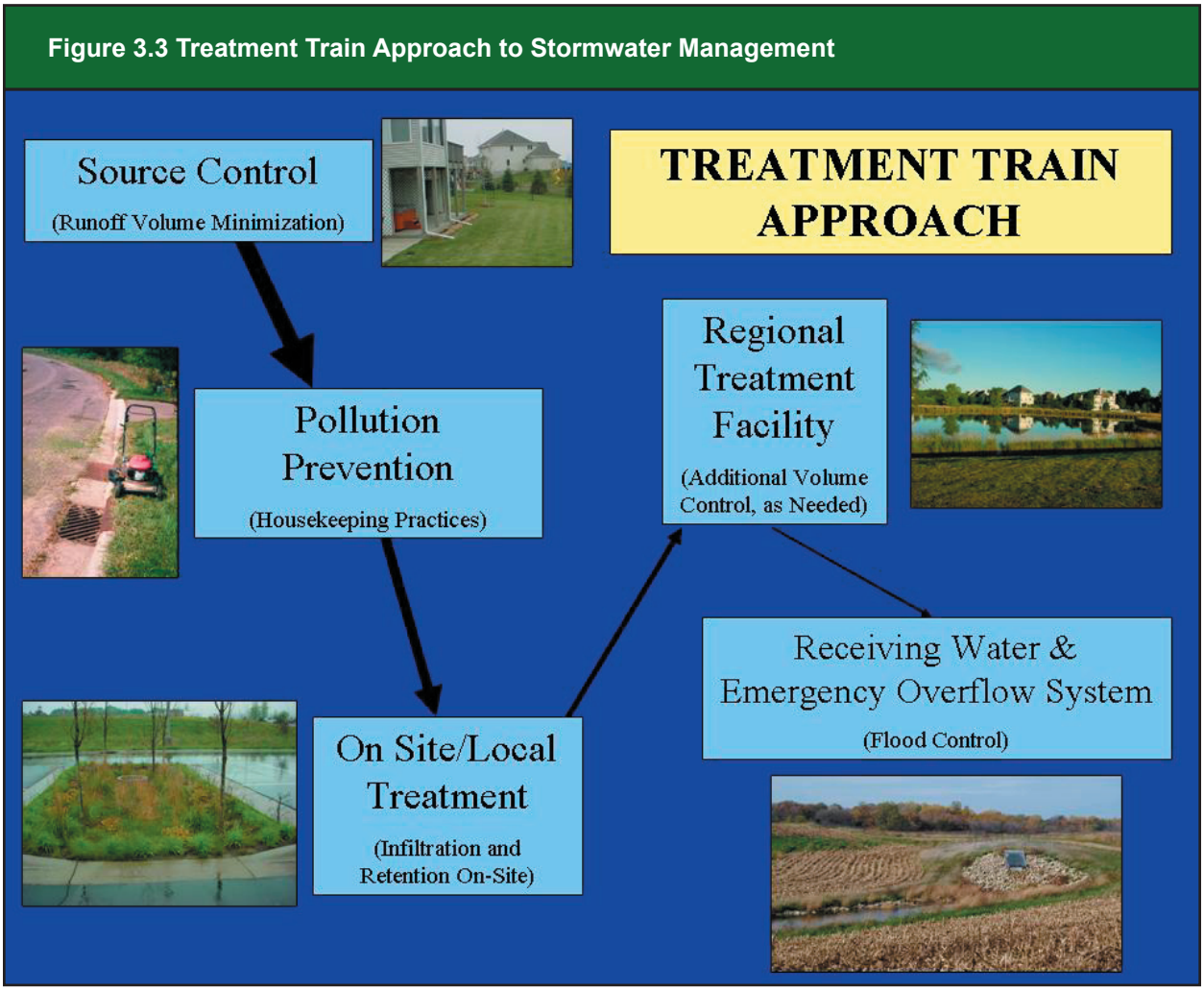
pollution of one water for another. Specific areas of caution in the NWA include areas of high ground water tables, tight soils, source water/wellhead protection areas, and stormwater hotspots (i.e.. discharges from gas stations or industrial areas).

Best Management Practices and the Treatment Train

Best management practices (BMPs) are proven, effective measures for managing stormwater runoff that are readily available to designers and managers in both structural and non-structural ways. While there are no "best" solutions that apply universally in every location and for every situation, there are best solutions that can be chosen for specific applications and to solve specific problems.

BMPs located in series can efficiently achieve several stormwater treatment objectives for both water quantity and water quality while optimizing use of space, on-site natural features, and available budget. This configuration, also called a "treatment train", consists of a series of BMPs each designated to address a different component of stormwater runoff with the goal of maximizing stormwater rate, volume control and pollutant removal (Figure 3.3).

Figure 3.3 Treatment Train Approach to Stormwater Management



Source: Adapted from Minnesota Stormwater Manual, 2005

The recommended approach to stormwater management for the NWA is organized around this treatment train approach with the goal being to start simply and increase complexity only as necessary to address the

unique situation found at each site. Beginning on-site with pollution prevention and simple runoff volume reduction, BMPs are progressively added to the treatment train first at the local level, and then at the regional level until stormwater management goals are met.

The first step in stormwater management is to reduce the amount of runoff generated on site by exposing precipitation to pervious areas and promoting infiltration. This includes design techniques such as reducing the impervious areas on the site, and disconnecting impervious surfaces. Because full runoff reduction is usually not possible, housekeeping activities to keep land surfaces clean, such as street sweeping and control of lawn clippings, is also a component in the treatment train to reduce exposing polluting materials to runoff.

When runoff cannot be controlled at the site, or polluting materials cannot be kept out of runoff, best management practices are designed to reduce the amount and rate of water leaving the site and of pollution that gets carried to downstream resources. Under this strategy, simple methods are used to keep water in place after rainfall or snowmelt events and potential pollutants are kept off of the land surface. Then, if needed, further controls are implemented to manage water that is moving within or away from the site. In addition to space and cost savings, the treatment train approach can increase the level and reliability of pollutant removal, increase the effective lifetime of a practice by removing suspended particulates prior to treatment in the downstream unit, and reduce the potential for re-suspension of deposited sediments by reducing flow energy levels or by providing longer flow paths for runoff.

Effective stormwater practices are integrated into the urban landscape to improve their function and performance. Twelve principles that help define the successful integration of a stormwater practice in the landscape are included in Table 3.2.

Table 3.2 Integrated Stormwater Design Principles

Principle	Goal
Provides reliable pollutant removal performance	The practice should be sized so that it captures sufficient volume of runoff and employs a sequence of pollutant removal mechanisms via a treatment train approach to maximize the removal of key pollutants of concern.
Mimics pre-development hydrology	The practice should operate in a manner so as to replicate pre-development hydrology for a range of storm events such that it safely recharges ground water, protects downstream channels and reduces off-site flood damage.
Integrates the practice into overall site design	The overall design of the site should support the function and performance of the practice, by minimizing or disconnecting impervious cover, implementing source controls, and utilizing better site design practices that reduce the quantity and adverse quality effects of runoff generated by the site.
Has a sustainable maintenance burden	Both routine and long–term maintenance tasks should be carefully considered throughout the design process to reduce life cycle maintenance costs and promote longevity of the practice.
Is accepted by the public	The practice should be viewed as an attractive community amenity by adjacent residents or business owners, as measured by interviews, surveys, testimonials, increased property values and other yardsticks.

Table 3.2 Integrated Stormwater Design Principles	
Principle	**Goal**
Creates attractive landscape features	The practice should be an integrated practice designed to be highly visible within the site and serve as an attractive and inviting landscape feature.
Confers multiple community benefits	An integrated practice should also contribute to other community benefits such as promoting neighborhood revitalization, expanding recreational opportunities, and educating residents about stormwater.
Creatively uses vegetation	An integrated practice not only greens up the site, but also uses vegetation to effectively promote cooling, shading, screening, habitat and enhanced pollutant removal functions. The design should also explicitly consider how vegetation will be managed over time to maintain functions and minimize maintenance costs.
Provides a model for future improvement	An integrated practice is inspected, evaluated, or monitored so that lessons can be learned to improve the performance and integrate future designs.
Realizes additional environmental benefits	The design of an integrated practice maximizes other environmental benefits at the site, such as the creation of aquatic or terrestrial habitat, protection of existing natural areas, reduction of urban heat island effects and other urban amenities.
Reduces infrastructure costs	An integrated practice reduces the amount of paving, curbs, storm drain pipes and other infrastructure that would have otherwise been employed in a traditional stormwater practice design within the community.
Acceptable life cycle costs	An integrated practice will not result in high life cycle costs over its useful life.

Source: Center for Watershed Protection

III. Integrated Stormwater Management Process

Project Scope

The first step in integrated stormwater management is to determine the scope of the project and the likely solutions that will be needed. For on-site treatment, simple practices will most likely solve the problem and a non- or minimum-structural approach can be pursued. If the downstream water body is more sensitive to stormwater impacts (Manage 1 or Manage 2 wetland classification) additional on site or regional treatment may be required.

Watershed Approach

For every project, the question that should always be asked is “Where does water come from that enters my site and where does it go?” This single question becomes the basis for a future management approach. For example, if the water leaving the site discharges to an infiltration basin rather than a lake, a different set of BMPs focusing on sediment control rather than nutrient removal will be pursued.

Use and Restoration of Natural Resources

The occurrence of natural features, such as wetlands, forest, natural drainage features, and open space on a site should be viewed as a positive attribute. Features such as these can be preserved to minimize the impact of development, used as an integral part of the treatment train, or even enhanced to improve site hydrology or the quality of runoff leaving the site.

Many of the basic tenets of “low impact development”, “better site design” and “sustainable development” are rooted in the preservation, restoration and enhancement of the natural drainage system. Following this approach can lead to site development cost savings, as well as added environmental protection and an increase in market value.

Water Quantity and Quality

Integrated stormwater management requires a complete look at both the volume and pollutant concentration of runoff water. Focusing exclusively on one or the other might meet a specific regulatory requirement, but will not result in effective overall stormwater management.

Rate and Volume Control

In its early stages, stormwater management was primarily concerned only with quantity control. Urban hydrology techniques focused mostly on rate control and addressed volume in terms of flood control. The standard approaches for rate control have been greatly refined over the years, with more attention on mimicking pre-development or natural conditions. The following section addresses the techniques that should be considered when a need exists to address stormwater quantity leaving a site.

Rate Reduction Techniques

In the past, rate control was primarily used to prevent downstream flooding. Relying solely on rate reduction for stormwater control led to many system failures as volume and quality factors were left uncontrolled. Although not universally true, advancement in the state of the art practices for rate control generally came about as urbanization increased and greater protection from water leaving these largely impervious places was needed.

Chapters within this manual go beyond flood protection to hydrograph frequency matching and rate control techniques designed to mitigate the effects of the commonly occurring events that account for most of the runoff. The following sections of this chapter and chapters 4, 6, and 7 provide information on the reasons for rate control and tools available to accomplish it.

Volume Reduction Techniques

The term “volume reduction” can be easily confused with “infiltration”. One does not, however, necessarily equate to the other. There are many additional techniques and BMPs that can be applied to yield volume reductions.

Any technique that allows water to soak into the ground, makes water available for evaporation and/or transpiration, stores water for re-use, or in any way diverts stormwater away from the drainage system can be considered a volume reduction practice. Infiltration is certainly one of these practices, but it is only one of many. In circumstances where soils are too tight or where infiltration would endanger ground water, many alternatives are available to reduce volume.

The following categorical methods for volume reduction, while certainly not all-inclusive, can provide some ideas for how a stormwater manager/designer could reduce the volume of runoff leaving a parcel of land.

Infiltration
The most commonly used method to reduce stormwater volume is to allow it to soak into the soil. The result of this action is a direct reduction in volume running off of the land surface. The biggest requirement for use of infiltration is the ability of the soil to accept the water.

Low Impact Development (LID), Better Site Design (BSD) and Sustainable Development are all variations of practices that mimic natural conditions by allowing water to soak into the ground close to where it falls. Use of these methods dramatically reduces overall runoff volume. Reduction of connected impervious area and retention of natural drainage patterns and surfaces are the heart of these methods.

Evapotranspiration
The combined process of evaporating and/or transpiring (vegetative uptake and release of water) is called evapotranspiration (ET). This process typically results whenever water is held in storage (evaporation, or sublimation of snow in the winter) and allowed to be taken up by roots and released through leaves (transpiration). In areas with tight soils, holding water in wetlands, depressions, swales or any similar land feature that exposes water to the air will result in evaporation of that water. In addition, allowing it to come in contact with roots either in standing water (wetland) or by soaking into the root zone, will yield volume reduction through transpiration.

Where soils provide a constraint, under-drains can provide a means through which water can be routed through the root zone for root uptake, but excess can be captured (after filtration) and drained to a collection system. This option results in some net reduction in volume and adds filtration as a supplemental treatment. Wetland treatment techniques take advantage of this method of volume reduction, as do under-drained bioretention (i.e. rain garden) facilities.

Routing water to areas where it can soak into the ground or to areas with vegetation that can take it up through root action are two very good ways to reduce overall stormwater volume.

Storage
Retaining water somewhere along the path from where it falls to where it enters a drainage system is another way to limit volume. Simple contained storage directly connected to buildings or impervious areas are effective volume reducers and provide an opportunity for water re-use. A rain barrel, cistern or even a yard ornamental pond can hold enough water to almost eliminate the entire volume coming from a home. A green roof can reduce annual runoff by up to 75% because it soaks and stores water that falls on it, then transpires it away. Even a pond or a wetland can reduce overall volume because they provide a quiescent area where water can collect and evaporate.

Conveyance
Getting rid of water was the common way to deal with stormwater before the results of that action were fully realized. Rushing water to a drain pipe, then into a receiving water is now considered a last resort when better options are not available. Using pervious approaches such as vegetated drainage swales and native grass filter strips, in combination with check dams give water a chance to soak into the ground or be filtered before it reaches a location where damage could be done. As with the practices above, volume reduction is an outcome of exposing stormwater to a pervious surface even while it is moving.

Landscaping
Many of the previous practices could also be included in a general category that stresses the importance of stable landscapes with native vegetation. In many respects, this is LID/BSD with an added emphasis on structuring the land surface to handle moving water from impervious surfaces. Routing water to low-lying (sump) areas where it can soak in, placing planter boxes or grated inlets for watering trees, and contouring slopes to reduce runoff velocity are all variations on the landscaping theme.

Tying low impact drainage features together via corridors or designed natural treatment trains can further enhance overall site volume reduction by creating a string of reduction possibilities. Safety can always be assured by placing an overflow or even an under-drain to capture any excess flow and route it to the next BMP catchment area.

Table 3.3 Volume Reduction Techniques

Process	BMP*	Comments	Location in Manual
Infiltration	LID/BSD/Sustainable Development	Includes such things as reduced street and sidewalk width, less curb and gutter drainage, scattered bioretention, shared pavement	Chapter 4
	Trench or basin	Must be properly engineered in adequate soils; proper maintenance essential	Chapter 9, Infiltration BMPs
	Perforated sub-surface pipes, tanks and storage systems	Expensive but effective and space-saving	Chapter 9, Infiltration Supplemental BMP sections
	Disconnected imperviousness	Includes primarily rooftop drains and roadway/ parking surfaces	Chapter 9, Runoff Volume Minimization
	Pervious surfaces	Includes a number of paving and block methods, or simple parking on reinforced grassed surfaces	Chapter 9, Runoff Volume Minimization
	Bioretention (if contains infiltration element)	Some bioretention facilities are designed to infiltrate	Chapter 9, Bioretention BMPs
Evapotranspiration	Bioretention (rain gardens)	Exposes runoff water to plant roots for uptake; can be under-drained and still effective	Chapter 9, Bioretention BMPs
	Vegetated swales	Exposes water surface during transport for evaporation and exposes runoff water to plant roots for uptake and evapotranspiration	Chapter 9, Filtration BMPs

Table 3.3 Volume Reduction Techniques			
Process	**BMP***	**Comments**	**Location in Manual**
Evapotranspiration	Wetland/pond storage	Combination of standing water surface and vegetative root exposure yields dramatic volume reductions through evapotranspiration	Chapter 9, Ponds and Wetland BMP sections
	Vegetated drainage corridor	Connecting numerous features increases opportunities	Chapter 4
	Recessed road/parking drainage	Routing paved surface runoff to vegetated sump areas keeps it out of receiving waters	Chapter 9, Bioretention BMPs
Storage	Rain barrel/cistern	Small-scale runoff collectors keep water around for later re-use or slow release	Chapter 9, Runoff Volume Minimization
	Rooftop (green roof)	Storage on a roof prevents water from leaving the site; combining with vegetation (engineered green roof) makes it even better	Chapter 9, Runoff Volume Minimization
	Wetland/pond storage	Combination of standing water surface and vegetative root exposure yields dramatic volume reductions	Chapter 9, Pond and Wetland BMP sections
Conveyance	Vegetated swale	Provides water a chance to soak into the ground and be filtered as it flows	Chapter 9, Bioretention BMPs
	Filter strips/buffers	Variation on vegetated swale with side slope protection	Chapter 9, Temporary Construction Erosion Control and Bioretention BMP sections

Table 3.3 Volume Reduction Techniques			
Process	**BMP***	**Comments**	**Location in Manual**
Landscaping	LID/BSD	Includes such things as scattered bioretention, shared pavement; native or prairie plantings	Chapter 4
	Bioretention (rain gardens)	Exposes runoff water to plant roots for uptake; can be under-drained and still effective	Chapter 9, Bioretention BMPs

Source: Adapted from Minnesota Stormwater Manual, 2005

Cautions for Volume Control Techniques

As with all stormwater management techniques, some caution is advised when applying them under certain circumstances. Following are some advisory cautions that would apply:

- Techniques using any infiltration should abide by the cautionary statements made in the Chapter 9 guidance sheet for infiltration practices and avoid such things as introduction of runoff from potential stormwater hotspots and use of infiltration practices that could influence drinking water wells.
- A hydrologic analysis should be undertaken to determine the impact of excessive water (flooding) on the installation; that is, where excess water would go and any problems that would result. Similarly, an assessment should be done on whether additional ground water volume is likely to cause any local problems, for example with flooded basements.
- Evapotranspiration values go down dramatically in the cold weather. Consideration is needed on how this may impact operation assumptions for installation.
- Chapter 6 contains mosquito breeding cautions and recommendations for minimization of mosquito breeding habitat for any system in Minnesota that results in standing water.

Pollution Prevention

The old adage "*An ounce of prevention is worth a pound of cure*" is never more appropriate than when used to describe integrated stormwater management. All of the elements above have described the physical processes involved, but preventing pollution from coming into contact with runoff is a common sense element. The simple separation of runoff and those materials that cause pollution, such as oil, fertilizer, salt and sediment, will go a long way toward controlling urban pollution problems at a very low cost.

Pollution prevention methods are far too numerous to cover in their entirety, but include such common-sense practices as keeping yard and animal waste off of impervious surfaces, preventing soil erosion at all construction sites, disposing of household products properly, repairing leaky automotive parts, and careful storage and use of any polluting chemicals. Following these simple precautions can make a dramatic difference in the type and amount of polluting material available for wash-off or aerial mobilization. An overview of pollution prevention techniques is presented in the Chapter 7 guidance.

IV. Link to Better Site Design

More detail on integrated stormwater management is part of the discussion in Chapter 4 on better site design (Insert link to Chapter 4). Better site design is used as an all-inclusive term that includes low impact development, sustainable development, design with nature or any other approach consistent with the treatment train design philosophy.

V. References

Bonestroo, Rosene, Anderlik, and Associates. 2004. Natural Resource Inventory and Management Plan for the Northwest Expansion Area.

Stormwater Steering Committee. 2005. The Minnesota Stormwater Manual. Minnesota Pollution Control Agency, St. Paul, MN. Available at: http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Connecticut Department of Environmental Protection. 2004. Connecticut Stormwater Quality Manual. Hartford, CT.

City of Inver Grove Heights. 2005. Northwest Area Alternative Urban Area Review. Inver Grove Heights, MN.

Federal Interagency Stream Restoration Working Group. 2000. Stream Corridor Restoration, Principles, Processes and Practices. Natural Resources Conservation Service.

Pitt, Robert. Article 104 from The Practice of Watershed Protection, editors Thomas R. Schueler and Heather K. Holland, published 2000 by the Center for Watershed Protection, Ellicott City, MD.

INVER GROVE HEIGHTS
Northwest Area

Chapter 4

Better Site Design Techniques

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Better Site Design Techniques

Chapter 4

Key Topics:	how to plan and apply better site design practices at new development projects, techniques that reduce impervious cover, conserve natural areas, and use pervious areas to more effectively treat stormwater runoff

Contents

I. Introduction..... 3
II. Preserving Natural Areas..... 3
III. Disconnecting and Distributing Stormwater..... 7
IV. Reducing Impervious Cover in Site Design..... 9
V. The Benefits of Better Site Design..... 14
VI. Applying Better Site Design..... 15
VII. References..... 19

I. Introduction

This chapter provides an overview for designers of the Better Site Design (BSD) techniques and how to plan and apply them at new development sites. Better site design includes a series of techniques that reduce impervious cover, conserve natural areas, and use pervious areas to more effectively treat stormwater runoff (Center for Watershed Protection, 1998a) and promote the treatment train approach to runoff management. The goal of better site design is to reduce runoff volume and mitigate site impacts when decisions are being made about proposed layout of a development site. These techniques are known by many different names, such as low impact development, design with nature, sustainable development and conservation design.

When applied early in the design and layout process, better site design techniques can sharply reduce stormwater runoff and pollutants generated at a development site, and also reduce the size and cost of both the stormwater conveyance system and stormwater management practices (Center for Watershed Protection, 1998b).

More than a dozen different better site design techniques can be applied early in the design process at development sites. While not all of the better site design techniques will apply to every development site, the goal is to apply as many of them as possible to maximize stormwater reduction benefits, as shown below:

Preserving Natural Areas

- Natural Area Conservation
- Site Reforestation or Restoration
- Shoreline Buffers
- Open Space Design

Disconnecting and Distributing Runoff

- Soil Compost Amendments and/or Soil Tilling
- Disconnection of Impervious Surfaces
- Rooftop Disconnection
- Grass Channels
- Stormwater Landscaping

Reducing Impervious Cover in Site Design

- Narrower Streets
- Slimmer Sidewalks
- Smaller Cul-de-sacs
- Shorter Driveways
- Smaller Parking Lots

II. Preserving Natural Areas

From a stormwater standpoint, it is desirable to maintain as much natural vegetative cover such as forest, prairie or wetland as possible. Natural areas generate the least amount of stormwater runoff and pollutant loads and establish and maintain the desired pre-development hydrology for the site. One of the first steps in the site planning involves identifying, conserving and restoring natural areas present at the development site. The overall strategy is to maximize natural area conservation beyond what is required under local or state resource requirements. Normally, an inventory of natural areas is conducted at the site, along with

an assessment of potential areas for reforestation or restoration. Next, designers modify the layout of the development project to take advantage of natural features, preserve the most sensitive areas, and mitigate any stormwater impacts. Open space design is one of the most effective better site design techniques for preserving natural areas at residential sites without losing developable lots.

Natural Area Conservation

Natural area conservation protects natural resources and environmental features that help maintain the pre-development hydrology of a site by reducing runoff and promoting infiltration (Figure 4.1). Examples include any undisturbed vegetation preserved at the development site, such as forests, prairies, and riparian areas; ridge tops and steep slopes, and stream, wetland and shoreline buffers. Designers should also place a particular priority on preserving natural drainage pathways, intermittent and perennial streams, and floodplains and their associated wetlands. Buildings and roads should be located around the natural topography and drainage so as to avoid unnecessary disturbance of vegetation, soils and natural drainage ways.

Figure 4.1 Residential Subdivision Illustrating Preservation of Natural Areas



Source: Arendt, 1997

The undisturbed soils and vegetation of natural areas promote infiltration, runoff filtering and direct uptake of pollutants. Forested areas intercept rainfall in their canopy, reducing the amount of rain that reaches the ground. Vegetation also pumps water back into the atmosphere which increases storage available in the soil. Native vegetation also prevents erosion by stabilizing soil, filtering sediment and pollutants from runoff, and nutrient uptake. Preserving natural areas creates many economic benefits including decreased heating and cooling costs, higher property values and improved habitat (Cappiella, 2005). Generally a natural grassland area would have to be five acres or larger to approach *full* ecological function, and a forested site would have to be in the range of 20-40 acres (DNR written correspondence, 2005).

Consult the Natural Resource Inventory and Management Plan for the Northwest Expansion Area (2004) for initial direction in determination of potential preservation areas.

Site Reforestation or Restoration

Site reforestation involves planting trees on existing turf or barren ground at a development site with the goal of establishing a mature forest canopy that can intercept rainfall, maximize infiltration and increase evapotranspiration (Figure 4.2).

Figure 4.2 Potential Planting Areas at a Development Site



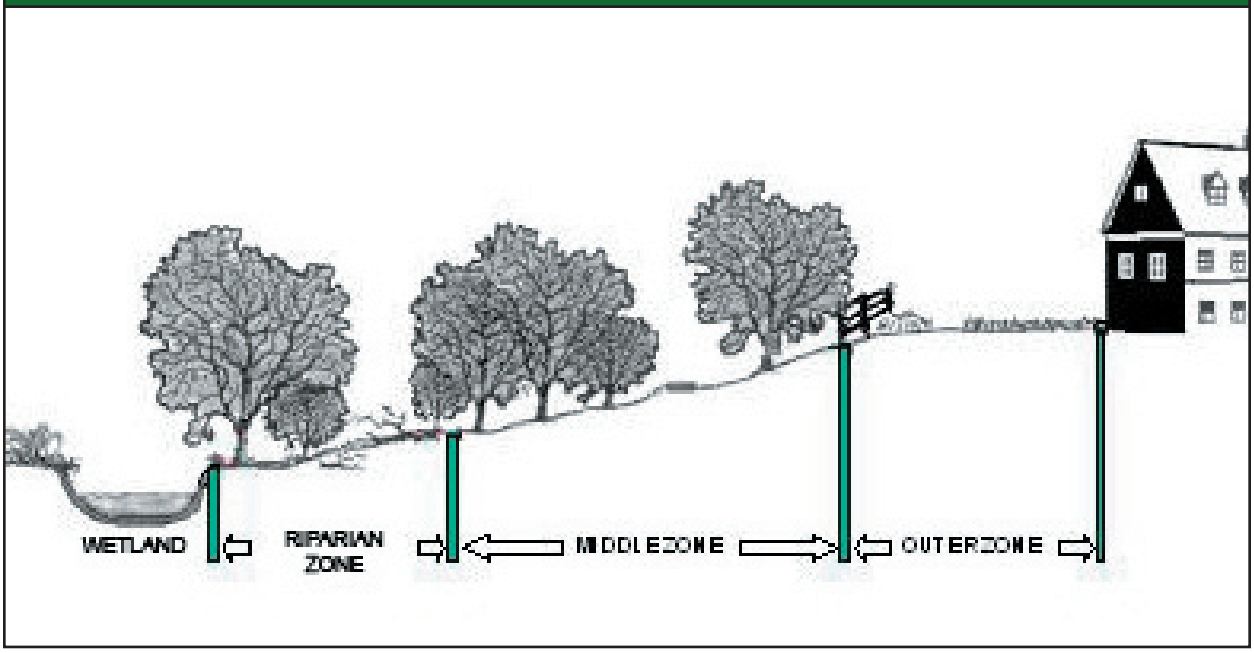
Source: Cappiella et. al. 2005

Reforestation is accomplished through active replanting or natural regeneration of forest cover. Cappiella (2005) reviewed a range of research that demonstrated the runoff reduction benefits associated with forest cover compared to turf cover. The benefits include reduced annual runoff volumes, higher rates of infiltration, reduced soil erosion, and greater uptake removal of stormwater pollutants. Forest soils actively promote greater infiltration rates due to surface organic matter and macro pores created by tree roots. Forests also intercept rainfall in their canopy, reducing the amount of rain that reaches the ground and increasing potential water storage in forest environments.

Shoreline Buffers

Many communities require buffers at development sites to provide a vegetative setback between development and streams, lakes or wetlands. While there are no streams, per se, in the NWA, grassed channels and stormwater conveyance routes can be managed as such to realize buffer benefits. The portions of a site reserved for buffers can present an excellent opportunity to practice better site design. The primary function of buffers is to physically protect a water course, lake or wetland from future disturbance or encroachment; however, with careful design they can also be used to capture and filter stormwater runoff from upland areas of the site. To optimize stormwater treatment, the outer boundary of the buffer (Figure 4.3) should have a

Figure 4.3 Three-Zone Stream Buffer System



Source: Adapted from Schueler, 1995

stormwater depression area and a grass filter strip. Runoff captured within the stormwater depression is spread across a grass filter designed for sheet flow conditions, and discharges to a wider forest or shrub buffer in the middle or riparian zones that can fully infiltrate and/or further treat storm flows.

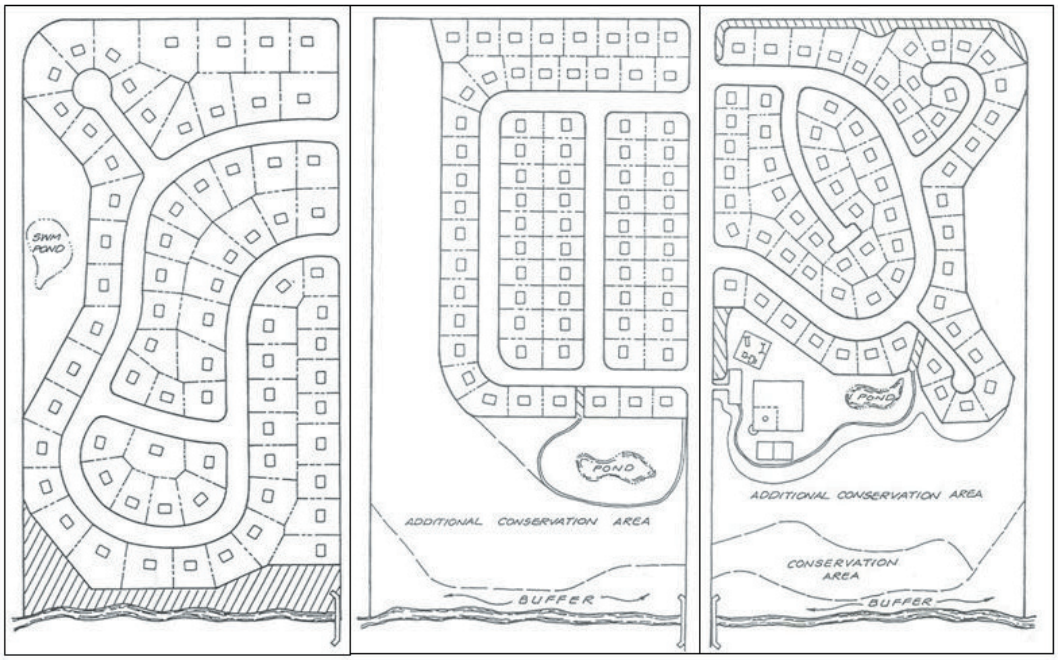
Buffers can provide many different environmental and economic benefits, including:

- Reduced small drainage problems and complaints
- Reduced risk of flood damage
- Reduced shoreline erosion
- Increased adjacent property values
- Enhanced pollutant removal
- Locations for greenways and trails
- Sustained integrity of ecosystems and habitat
- Protection of wetlands associated with the corridor
- Prevention of disturbance of steep slopes
- Mitigation of thermal impacts
- Protection of habitat for wildlife

Open Space Design

Open space design is a form of residential development that concentrates lots in a compact area of the site to allow for greater conservation of natural areas (Figure 4.4). Minimum lot sizes, setbacks and frontage distances are relaxed so as to maintain the same number of dwelling units at the site. This form of development may also be called cluster design or conservation design. Since open space design is available as an option under local zoning codes, it can be an excellent tool to conserve more natural areas beyond the minimum required under local and state water resource protection ordinances. Open

Figure 4.4 Conventional Subdivision (left) with 72 Lots, and Alternative Layout (center) Using Open Space Design with the same number of Lots, and Another Alternative Layout (right) Using Open Space Design with 66 Lots



Source: Schueler, 1995

space design can also be used to reduce or disconnect impervious cover and provide for greater on-site stormwater treatment. The natural areas conserved are protected by easement and managed by a community or homeowners association.

Research has shown that open space designs can reduce overall site impervious cover compared to conventional subdivisions, and command higher prices and more rapid sales, as well (Zielinski, 2001). Other benefits include lower costs for grading, erosion control, stormwater and site infrastructure, as well as greater land conservation, without the loss of developable lots.

III. Disconnecting and Distributing Stormwater

Another Better Site Design strategy seeks to maximize the use of pervious areas at the site to help filter and infiltrate runoff generated from impervious areas and to spread excess runoff over pervious areas. Most development sites have extensive areas of grass or landscaping where runoff can be treated close to the source where it is generated. Designers should carefully look at the site for pervious areas that might be, used to disconnect or distribute runoff. The benefits of this strategy include systematic reductions in runoff volumes, reductions in runoff velocities that can lead to flooding and improved water quality by filtering.

Compost and Amended Soils

Compost amended soils are used to recover soil porosity lost due to compaction as a result of past construction, soil disturbance and ongoing human traffic. The amendment process seeks to recover the porosity and bulk density of soils by incorporating soil amendments or conditioners into the lawn, such as compost, top soil, lime and gypsum (McDonald, 1999).

Soils can also be amended through the addition of fibers for structural support to prevent compaction, as well as the simple addition of sand to improve permeability or organic material other than compost (e.g. peat).

Soils are the foundation for successful planting, and the water holding capacity of soils can significantly reduce the volume of runoff from a site. What constitutes a “good” soil depends on the purpose it is to serve. For example, if you are planting prairie plants a high organic content in the soil is required. However, if you are planting Kentucky Bluegrass a lower organic content soil can be used.

In addition to successful plant growth, soils can be engineered to improve water holding capacity. The humus materials or compost created from the compost process has a water holding capacity of up to 80 percent by weight. This quality is very significant when trying to decrease runoff and increase filtration. Higher organic content in the soil also improves the filtering and binding capacity of soils for capturing pollutants.

On-site soils can be amended by incorporating compost into the soils or by laying a one to three inch “blanket” of compost on top of the soils. Fiber amendments can assist in maintaining soil structure even with heavy surface loads. The method chosen depends on site characteristics and the purpose it is intended to serve, such as promoting infiltration or reducing nutrient and sediment loading to surface waters.

Disconnection of Surface Impervious Cover

Surface disconnection spreads runoff from small parking lots, courtyards, driveways and sidewalks into adjacent pervious areas where it is filtered or infiltrated into the soil. Designers look for areas of the site where flow can be diverted onto turf, lawns or a vegetated filter strip. When many small areas of impervious cover are disconnected from the storm drain system, the total volume and rate of stormwater runoff can be sharply reduced. Disconnections may be restricted based on the length, slope, and soil infiltration rate of the pervious area in order to prevent any reconnection of runoff with the storm drain system. In some cases, minor grading of the site may be needed to promote overland flow and vegetative filtering.

Rooftop Disconnection

Disconnection of rooftops offers an excellent opportunity to spread runoff over lawns and other pervious areas where it can be filtered and infiltrated. Downspout disconnection can infiltrate runoff, reduce runoff velocity, and remove pollutants. Alternately, downspouts can be directed to a dry well, rain garden or surface depression. The stormwater benefits associated with rooftop disconnection can be significant, particularly when residential lot size is large and soils are relatively permeable. Note that building sub-drains generally intercept water from entering a building and do not lend themselves to the impervious disconnection category.

Grass Channels

Curbs, gutters and storm drains are all designed to be hydraulically efficient in removing stormwater from a site. However, they also increase peak runoff discharge, flow velocity, and pollutant delivery to downstream waters. From a better site design perspective, grass channels are preferable to curb and gutters as a conveyance system, where development density, topography, soils and slopes permit their use. Grass channels provide on-site runoff storage, lower peak flows, reduce runoff velocities, and filter or infiltrate some portion of storm flows. While research has indicated that grass channels cannot remove pollutants reliably enough to qualify as a BMP (Winer, 2000), they have been shown to reduce runoff volumes during smaller storms when compared to curbs and gutters.

Stormwater Landscaping

Traditionally, landscaping and stormwater management have been treated separately in site planning. In recent years, engineers and landscape architects have discovered that integrating stormwater into landscaping features can improve the function and quality of both. The basic concept is to adjust the

planting area to accept stormwater runoff from adjacent impervious areas and utilize plant species adapted to the modified runoff regime (Table 4.1). Excellent guidance on how to match plant species to stormwater conditions can be found in the MPCA publication *Plants for Stormwater Design: Species Selection for the Upper Midwest* (Shaw and Schmidt, 2003) and in Cappiella *et al.* (2005).

Table 4.1 Environmental Factors to Consider When Integrating Stormwater and Landscaping

Factor	Problem Addressed
Duration and depth of inundation	Increased duration and depth of water changes the physical and chemical environment in ways that may favor Invasive plants
Frequency of inundation	Increased frequency of inundation can carry increased levels of pollutants and toxins
Available moisture during dry weather	Soil compaction can affect plant species success at a site and also the ability of the soil to infiltrate stormwater efficiently
Sediment loading	Susceptibility to erosion and sedimentation from stormwater affects placement of stormwater management BMP as well as selection of plant material
Salt exposure	Browsers (deer and beaver) may be attracted by increased levels of salt in areas that treat roadway and parking lot runoff
Nutrient loading	Increased slopes increase ability to transport nutrients in stormwater

Source: Adapted from Shaw and Schmidt, 2003

A landscaping area may provide full or partial stormwater treatment, depending on site conditions. An excellent example of the use of landscaping for full stormwater treatment is bioretention (Figure 4.5). In other cases, landscaping can provide supplemental treatment such as green rooftops and stormwater planters. Even small areas of impervious cover should be directed into landscaping areas since stormwater or melt water help to reduce irrigation needs. More specific recommendations on the use of landscaping in BMP design can be found in Chapter 8 and Appendix B.

IV. Reducing Impervious Cover in Site Design

This strategy relies on several techniques to reduce the total area of rooftops, parking lots, streets, sidewalks and other types of impervious cover created at a development site. The basic approach is to reduce each type of impervious cover by downsizing the required minimum geometry specified in current local codes, keeping in mind that there are minimum requirements that must be met for fire, snowplow and school bus operation. Less impervious cover directly translates into less stormwater runoff and pollutant loads generated at the site.

Figure 4.5 Examples of the Use of Landscaped Islands for Stormwater Treatment in a Suburban Parking Lot (left), the Parking Lot of a Government Office Building (top right), and a Highly Urban parking Lot (bottom right).



Source: Minnesota Stormwater Manual, 2005

Narrower Streets

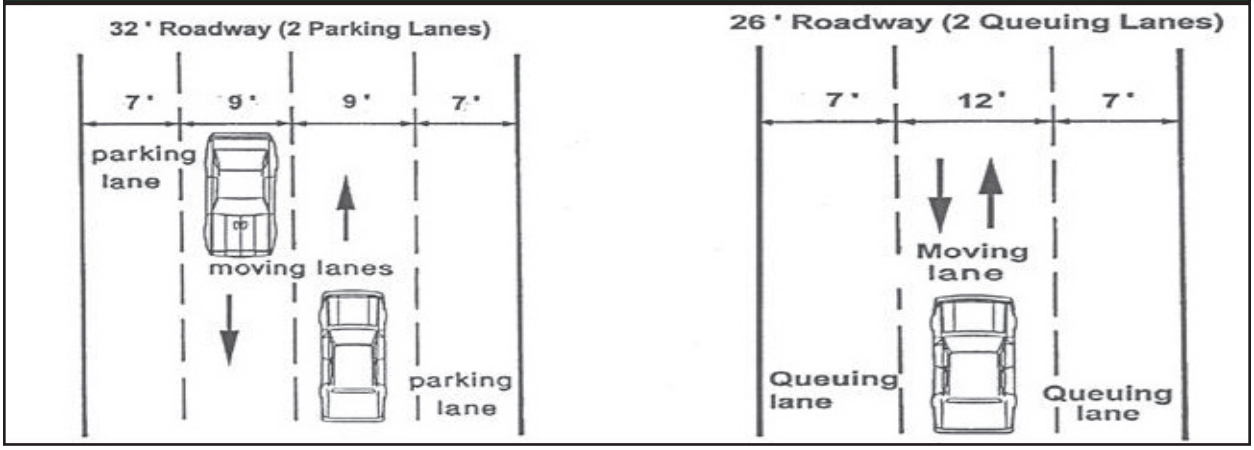
Many communities require residential streets that are much wider than needed to support travel lanes, on-street parking, and emergency access. Some communities currently require residential streets as wide as 32 to 40 feet and which provide two parking lanes and two moving lanes (Figure 4.6). Local experience has shown that residential streets can have pavement widths as narrow as 22 to 26 feet, and still accommodate all access and parking needs (ITE, 1997). Even narrower access streets or shared driveways can be used when only a handful of homes are served. Narrower streets help reduce impervious cover and associated runoff and pollutant generation.

Significant cost savings occur in both road construction and maintenance. Narrower streets also help reduce traffic speeds in residential neighborhoods which, in turn, improve pedestrian safety. Snow stockpiles on narrow streets can be accommodated if parking is restricted to one side of the street or alternated between the sides. Alternatively, the right-of-way may be used for snow storage. Narrow snowplows are available. Snowplows with 8' width, mounted on a pick-up truck are common. Some companies manufacture alternative plows on small bobcat-type machines.

Slimmer Sidewalks

Many communities require sidewalks that are excessively wide or are located adjacent to the street where the pedestrians are at risk from vehicles. A better site design technique modifies the width and location of sidewalks to promote safer pedestrian mobility (Figure 4.7). Impervious cover is reduced when sidewalks are required on only one side of the street, reduced in width and are located away from the street. Sidewalks can also be disconnected so they drain to lawns or landscaping instead of the gutter and storm drain

Figure 4.6 Example of a Traditional Road Design (left) and a Road that was Narrowed Through the Use of "Queuing" lanes (right)



Source: Minnesota Stormwater Manual, 2005

Figure 4.7 Sidewalk that Drains to Adjacent Vegetation and Provides Common Walkways Linking Pedestrian Areas



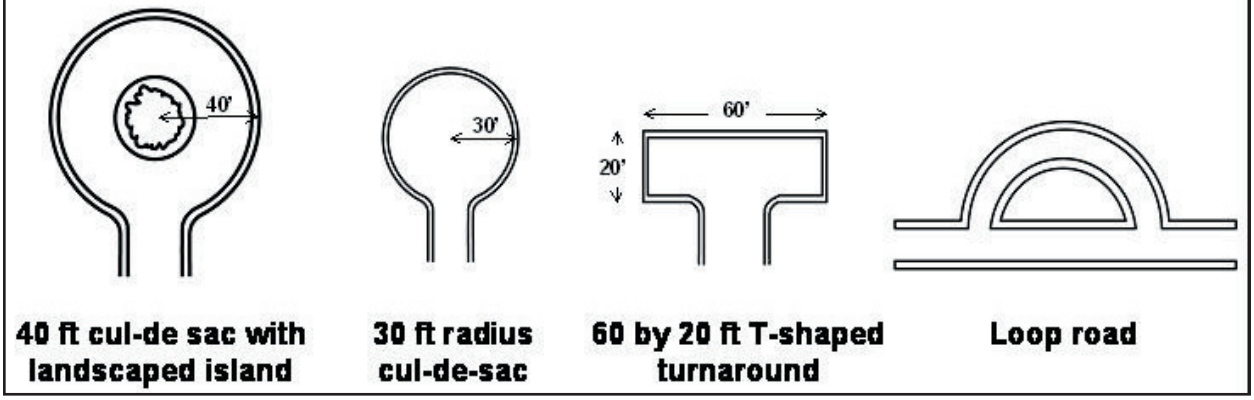
Source: Minnesota Stormwater Manual, 2005

system. Slimmer sidewalks reduce and/or disconnect impervious cover and thus reduce the generation of runoff. Other benefits include greater pedestrian safety, lower construction and maintenance costs, and reduced individual homeowner responsibility for snow clearance.

Smaller Cul-de-Sacs

The large cul-de-sacs that enable vehicles to turn around at the end of a residential street provide a great opportunity for better site design. Impervious cover can be reduced by minimizing the diameter of residential street cul-de-sacs and/or incorporating landscaped islands. Many communities require cul-de-sacs that have a greater diameter than needed to allow emergency and large vehicles to adequately turn around. Alternatives to the traditional 80 foot diameter cul-de-sac include 60 foot diameter cul-de-sacs, hammerhead turnarounds and loop roads (Figure 4.8).

Figure 4.8 Turnaround Options for Residential Streets



Source: Adapted from Schueler, 1995

In addition, the inside of the turnaround can be landscaped as a bioretention area to further reduce impervious cover and improve stormwater treatment. Trees and vegetation planted in landscaped islands can be used to intercept rain water and treat stormwater runoff from surrounding pavement (Figure 4.9). Each of these alternative turnaround options produces a more attractive and safe environment for residents.

Figure 4.9 Trees and Vegetation Planted in the Landscaped Island of a Cul-de-sac (left) and a Loop Road (right)



Source: Minnesota Stormwater Manual, 2005

Smaller Parking Lots

The parking lot is an excellent place to apply better site design. In many communities, parking lots are over-sized and under-designed. Local parking and landscaping codes can be modified to allow the following better site design techniques to be applied within parking lots:

- Minimize standard stall dimensions for regular spaces
- Provide compact car spaces
- Use of pervious pavement (asphalt, concrete, pavers, sand amendments)
- Incorporate efficient parking lanes
- Reduce minimum parking demand ratios for certain land uses
- Treat the parking demand ratio as a maximum limit
- Create stormwater "islands" in traffic islands or landscaping areas to treat runoff using bioretention, filter strips or other practices
- Encourage shared parking arrangements
- Proof of Parking

Smaller parking lots can sharply reduce impervious cover and provide more effective treatment of stormwater pollutants. In addition, smaller parking lots reduce both up front construction costs and long term operation and maintenance costs, as well as the size and cost of stormwater practices. Parking lot landscaping makes the lot more attractive to customers, and promotes safety for both vehicles and pedestrians. In addition, trees and other landscaping help screen adjacent land uses, shade people and cars, reduce summertime temperatures and improve air quality and bird habitat.

Shorter Driveways

Driveways present another opportunity to practice better site design. Most local codes contain front yard setback requirements that dictate driveway length. In many communities, front yard setbacks for certain residential zoning categories may extend 50 or 100 feet or even longer, which increases driveway length well beyond what is needed for adequate parking and access to the garage. Shorter setbacks (20 feet are allowed in the NWA) reducing the length and impervious cover for individual driveways. In addition, driveway width can be reduced, and more permeable driveway surfaces allowed. Another way to reduce

Figure 4.10 Example of a Shorter Driveway (left) and a Shared Driveway (right)



Source: Minnesota Stormwater Manual, 2005

impervious cover is to allow shared driveways that provide street access for up to six homes (Figure 4.10). Shorter driveways help reduce infrastructure costs for developers since they reduce the amount of paving or concrete needed.

V. The Benefits of Better Site Design

Several researchers have employed redesign comparisons to demonstrate the benefits of better site design over a wide range of residential lot sizes and commercial applications. For example, Center for Watershed Protection (1998b) demonstrated that better site design techniques could reduce impervious cover and stormwater runoff by 7 to 70%, depending on site conditions. Figure 4.11 illustrates a redesign analysis for

Figure 4.11 Comparative Analysis of Stonehill Estates in the Pre-Development Condition, Conventional Design, and Open Space Design



Source: Center for Watershed Protection, 1998

a medium density residential subdivision. The analysis suggested that better site design techniques could reduce impervious cover and annual runoff volume by 24%, cut phosphorus loadings by half, and increase site infiltration by 55%, compared to a traditional subdivision.

Each better site design technique provides environmental and economic benefits to both the developer and the community at large. When techniques are applied together at a development site, they can result in tangible savings for the developer in the form of:

- Reduced infrastructure costs (e.g., paving and piping)
- Reduced clearing and grading costs during construction
- Smaller and less costly structural stormwater BMPs
- Faster sales and lease rates
- Easier compliance with wetland and other resource protection regulations
- More land available for building since fewer structural BMPs are needed

Cost savings really start to add up when many better site design techniques are applied together. Some research indicates that infrastructure savings alone can range from 5 to 65%, depending on site conditions, lot size and the extent that better site design techniques are applied (Cappiella *et al,* 2005; Center for Watershed Protection, 1998b; Liptan and Brown, 1996; Dreher and Price, 1994; and Maurer, 1996).

Better site design techniques continue to provide benefits to the community long after the developer has sold the lots. Some examples of these benefits include:

- Reduced operation and maintenance costs for roads and stormwater system
- Increased property values for homes and businesses
- Increased open space available for recreation
- More pedestrian friendly neighborhoods
- Reduced annual cost for mowing
- More pleasing and attractive landscaping
- Improved air quality (more forest cover)
- Less temperature fluctuation from paved surfaces

Table 4.2 compares the economic and environmental benefits that can be expected for individual better site design techniques.

VI. Applying Better Site Design in the NWA

Typically the application of better site design techniques is difficult because local subdivision codes and zoning ordinances discourage or even prohibit their use. This is not the case however in the Northwest Area of the City of Inver Grove Heights. The Northwest Area Planned Unit Development Overlay District (Zoning Ordinance Subd. 39) contains significant flexibility and language requiring the use of better site design techniques intended to promote the conservation of natural areas and reduce the generation of stormwater runoff.

Table 4.3 identifies the PUD language that corresponds to each of the better site design techniques presented in this Chapter of the Manual.

Table 4.2 Comparison of Benefits Provided by Better Site Design Techniques*

Better Site Design Technique	Minimizes Land Disturbance	Preserves Vegetation & Habitat	Lowers Capital Costs	Lowers O&M** Costs	Raises Property Value
Natural Area Conservation	●	●	●	●	◐
Site Reforestation	◐	●	○	●	●
Stream and Shoreline Buffers	●	●	●	●	◐
Open Space Design	●	●	●	●	◐
Soil Compost Amendments	◐	●	○	◐	○
Surface IC Disconnection	◐	◐	●	◐	○
Rooftop Disconnection	◐	◐	●	●	◐
Grass Channels	◐	◐	●	◐	◐
Stormwater Landscaping	◐	●	○	◐	●
Narrower Streets	●	◐	●	●	◐
Slimmer Sidewalks	◐	◐	●	●	◐
Smaller Cul-de-sacs	◐	◐	●	●	◐
Shorter Driveways	●	◐	●	●	◐
Smaller Parking Lots	◐	◐	●	●	◐

Key:

● = often provides indicated benefit

◐ = sometimes provides a modest benefit

○ = does not provide benefit

*Comparison is intended for general purposes; and will vary on a site-by-site basis.
**O&M = Operation and Maintenance

Source: Minnesota Stormwater Manual, 2005

Table 4.3 Better Site Design Techniques Identified in Zoning Ordinance Subd. 39	
Better Site Design Techniques	**Better Site Design Techniques Identified in PUD or other Regulatory Document**
Preserving Natural Areas	
Natural Area Conservation	An amount of land equal to at least 20% of the net developable area within the PUD shall be preserved as additional natural area/open space, which may include greenways as shown in the Inver Grove Heights Natural Resources Inventory and Management Plan (BRAA, 2004) (Subd. 39 G.4.a)
Open Space Design	Promotes open space design or cluster development by allowing an increased mixture of housing types for each zoning district (Subd. 39 G.5.a)
Shoreline Buffers	The wetland management standards assign slope-dependent buffer widths to each wetland management classification
Disconnecting and Distributing Runoff	
Soil Compost Amendments or Tilling	Identified in the Inver Grove Heights Stormwater Manual as a best management practice that may be used to meet the volume control standard.
Disconnection of Surface Impervious Cover	▶ Parking lot curbs shall be designed to meet the standards set forth in the City of Inver Grove Heights Stormwater Manual so as to insure safety and best management of stormwater. Generally curbs shall either be flat or have breaks at regular intervals to convey runoff into the stormwater system unless a stormwater management plan demonstrates that another curbing system meets the stormwater management performance objectives (Subd. 39 H.2.d) ▶ Surface parking lots in excess of 100 spaces shall provide landscaped islands between double loaded rows of parking. Such landscaped islands shall also serve as a stormwater cell and shall be designed according to the guidelines established in the City of Inver Grove Heights Stormwater Manual (Subd. 39 H.2.j) ▶ Cul-de-sacs can be designed with larger diameters provided a landscaped island is included and designed for stormwater storage. Landscaped medians are encouraged to be designed in cul-de-sac bulbs to handle stormwater runoff and provide a place for snow storage during snow season. (Subd. 39 I.1.e)
Rooftop Disconnection	▶ All residential downspouts and sump pumps shall discharge to cisterns and/or permeable surfaces (Subd. 39 H.4.a) ▶ All non-residential downspouts and sump pumps shall discharge to permeable surfaces if reasonably possible (Subd. 39 H.4.b)

Table 4.3 Better Site Design Techniques Identified in Zoning Ordinance Subd. 39	
Better Site Design Techniques	**Better Site Design Techniques Identified in PUD or other Regulatory Document**
Grass Channels	Parking lot curbs shall be designed to meet the standards set forth in the City of Inver Grove Heights Stormwater Manual so as to insure safety and best management of stormwater. Generally curbs shall either be flat or have breaks at regular intervals to convey runoff into the stormwater system unless a stormwater management plan demonstrates that another curbing system meets the stormwater management performance objectives (Subd. 39 H.2.d)
Stormwater Landscaping	…the use of natural plant materials for landscaping is encouraged in common areas (Subd. 39 H.1)
Reducing Impervious Cover in Site Design	
Narrower Streets	▶ Local public streets shall have a 28 foot paved width in addition to a sidewalk or trail on one side of the street. This street dimension shall restrict parking to only one side of the street (Subd. 39 I.1.c(ii)) ▶ Local private streets with a 24 foot width shall be acceptable with no parking on either side (Subd. 39 I.1.c(iii))
Smaller Cul-de-sacs	▶ Designed with a turn-around having an outside roadway radius of 35 feet and a street property line (ROW) radius of 50 feet (Subd. 39 I.1.e)
Shorter Driveways	▶ Driveway widths for single-family detached residential dwellings, two family and twin home dwellings shall be no more than 20 feet. In all other cases it shall be no more than 32 feet (Subd. 39 H.3.a) ▶ Shared driveways are encouraged… (Subd. 39 H.3.b) ▶ PUD identifies minimum and maximum front yard setbacks for various land uses (Subd. 39 G.3.b)
Smaller Parking Lots	▶ Joint parking arrangements encouraged in the Northwest Area Overlay District (Subd. 39 H.2.a) ▶ The PUD re-establishes the minimum required off-street parking spaces and established a minimum allowed number of parking spaces as well (Subd. 39 H.2.e) ▶ 50% of total parking required for Multi-Family and Mixed Use development shall be underground parking, tuck-under parking or structured parking within or under the principal structure. The intent of this regulation is to minimize impervious surface that would result from surface parking lots (Subd. 39 H. 2. f)

Table 4.3 Better Site Design Techniques Identified in Zoning Ordinance Subd. 39	
Better Site Design Techniques	**Better Site Design Techniques Identified in PUD or other Regulatory Document**
Pervious Surfaces	▶ Parking surfaces may be made of pervious materials such as pavers, pervious asphalt or concrete or other technology as identified in the Stormwater Manual (Subd. 39 H.2.c) ▶ Pervious paving materials shall/may be used for that portion of parking over the minimum required off-street parking spaces (Subd. 39 H.2.g) ▶ Single-family residential driveways are encouraged to be constructed of pervious materials such as pavers, pervious concrete or pervious asphalt (Subd. 39 H.3.c) ▶ Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of permanent pervious surface such as brick pavers, pervious concrete/asphalt or other technique as approved through the City of Inver Grove Heights Stormwater Manual (Subd. 39 H.3.a)

VII. References

Arendt, R. 1997. Designing Open Space Subdivisions. Natural Lands Trust. Media, PA

Cappiella, K. 2005a. Urban Watershed Forestry Manual Part 1: Conserving Trees at the Watershed Scale. Prepared for: USDA Forest Service. Center for Watershed Protection. Ellicott City, MD.

Cappiella, K., T. Schueler, and T. Wright. 2005b. Urban Watershed Forestry Manual Part 2: Conserving and Planting Trees at Development Sites. Prepared for: USDA Forest Service. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP). 1998a. Better Site Design: A Handbook for Changing Development Rules in Your Community. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP). 1998b. Nutrient Loading From Conventional and Innovative Site Development. Prepared for: Chesapeake Research Consortium. Center for Watershed Protection. Ellicott City, MD.

Chicago Wilderness and Northeastern Illinois Planning Commission, 2003. Conservation Design Resource Manual. Available at http://www.chicagowilderness.org/

County Board of Supervisors of the County of Dane. 2005. Chapter 14 of the Dane County Code of Ordinances Regarding Erosion Control and Stormwater Management. Dane County, WI.

Delaware Department of Natural Resources and Environmental Conservation (DE DNREC). 1997. Conservation Design for Stormwater Management. Dover, DE.

Dreher, D, and T. Price. 1994. Reducing the Impact of Urban Runoff: The Advantages of Alternative Site Design Approaches. Northeastern Illinois Planning Commission. Chicago, IL.

Illinois Conservation Foundation and Chicago Wilderness, 2005. Changing Cost Perceptions: An Analysis of Conservation Development. Prepared by the Conservation Research Institute. http://www.nipc.org/environment/sustainable/conservationdesign/cost_analysis/

Institute of Transportation Engineers Transportation Planning Council Committee 5P-8 (ITE). 1997. Traditional Neighborhood Development Street Design Guidelines. Institute of Transportation Engineers. Washington, DC.

King County Department of Development and Environmental Services. 2005. Achieving the Post-Construction Soil Standard. King County, Washington.

Liptan, T. and C. Brown. 1996. A Cost Comparison of Conventional and Water Quality-based Stormwater Designs. City of Portland. Portland OR.

Maurer, G. 1996. A Better Way to Grow: For More Livable Communities and a Healthier Chesapeake Bay. Chesapeake Bay Foundation. Annapolis, MD.

McDonald, F. 1999. Ecologically Sound Lawn Care for the Pacific Northwest: Findings from the Scientific Literature and Recommendations from Turf Professionals. City of Seattle Public Works. Seattle, WA.

Metropolitan Council. 2001. Urban Small Sites Best Management Practice Manual. St. Paul, MN.

Minnesota Department of Natural Resources. 2003. Field Guide to the Native Plant Communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR St. Paul, MN.

Minnesota Department of Natural Resources. 2005. Field Guide to the Native Plant Communities of Minnesota: The Eastern Broadleaf Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR St. Paul, MN.

Minnesota Department of Natural Resources. 2006. Field Guide to the Native Plant Communities of Minnesota: The Prairie Parkland and Tallgrass Aspen Parklands Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR St. Paul, MN.

Minnesota Pollution Control Agency. 2000. Protecting Water Quality in Urban Areas: Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban, and Developing Areas of Minnesota. St. Paul, MN.

Schueler, T. 1995. Site Planning for Urban Stream Protection. Center for Watershed Protection. Ellicott City, MD

Shaw, D. and R. Schmidt, 2003. Plants for Stormwater Design - Species Selection for the Upper Midwest. Edited by S. Brungardt, Designed by R. Harrison, Minnesota Pollution Control Agency, St. Paul, MN.

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Prepared for: U.S. EPA Office of Science and Technology. Center for Watershed Protection. Ellicott City, MD.

Zielinski, J., 2001. The Benefits of Better Site Design in Residential Subdivisions. Watershed Protection Techniques, 3(2):633-646. Center for Watershed Protection. Ellicott City, MD.

INVER GROVE HEIGHTS
Northwest Area

Chapter 5

Best Management Practices

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Best Management Practices

Chapter 5

Key Topics:	**Introduction to the selection of best management practices (BMPs), selection of BMP suite or specific practice, seven key factors in BMP selection, and comparative BMP information**

Contents

I. Introduction..... 3
II. Using the Treatment Train Approach to BMP Selection..... 3
III. Process for Selecting Best Management Practices.... 7
IV. BMP Selection Matrix..... 20
V. References..... 25

I. Introduction

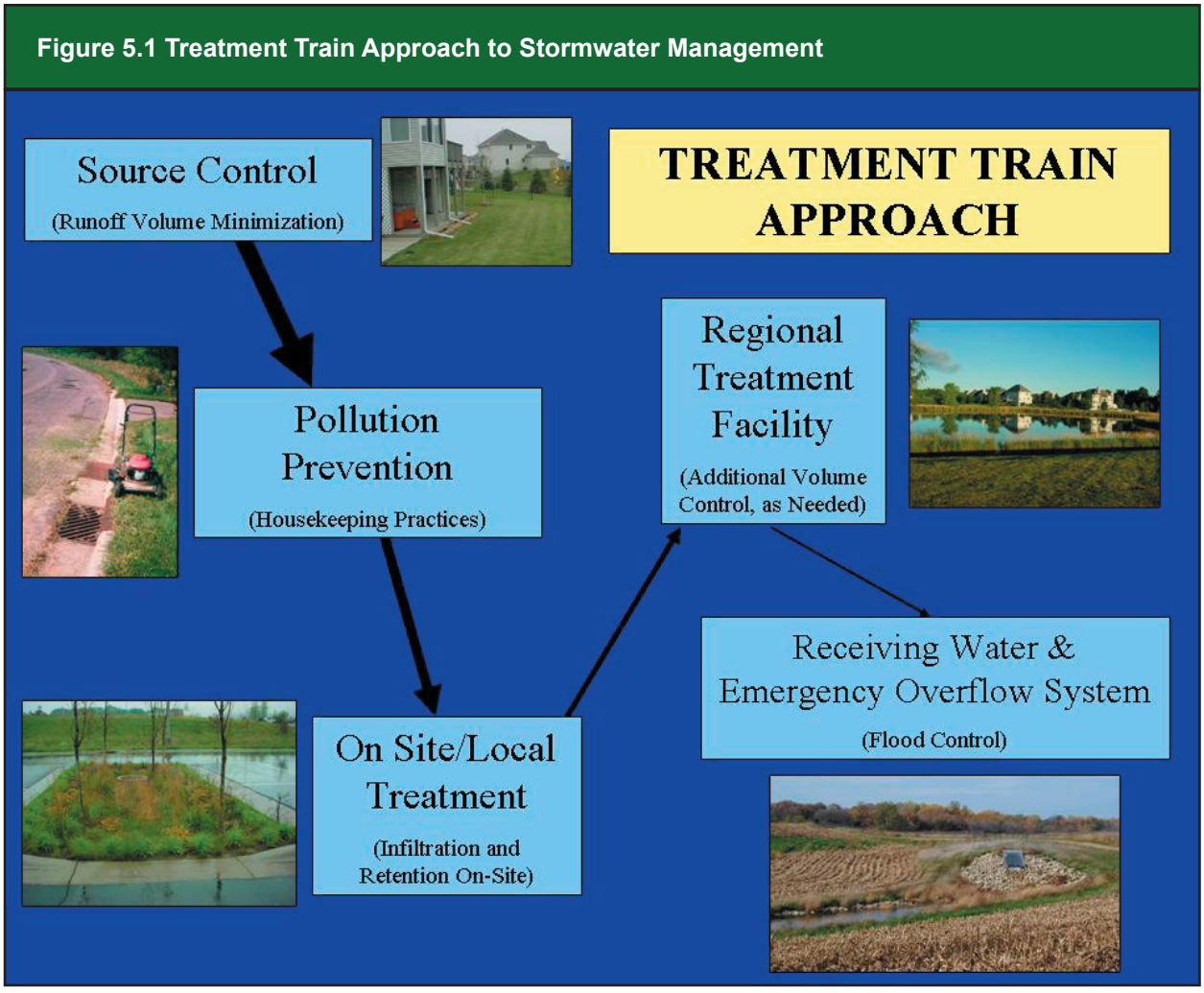
Chapter 5 is intended to provide the Designer with an introduction to the BMPs recommended for the NWA of Inver Grove Heights. The first section of the chapter identifies the BMPs and the second section introduces the Designer to the main factors that should be evaluated in selecting a BMP or group of BMPs to meet the City's stormwater management requirements. All of this information is summarized in a matrix that can be found at the end of the chapter (see Table 5.8). The intent of this matrix is to facilitate the evaluation of suitable BMPs for particular applications. More detailed information regarding individual design and construction considerations is provided in Chapter 8 of this Manual.

II. Using the Treatment Train Approach to BMP Selection

Introduction to Treatment Train

The basic premise for selection of a Best Management Practice (BMP) or group of BMPs is to follow the treatment train approach introduced in Chapter 1. Under the treatment train approach illustrated in Figure 5.1, stormwater management begins with simple methods that minimize the amount of runoff that occurs from a site and methods that prevent pollution from accumulating on the land surface and becoming

Figure 5.1 Treatment Train Approach to Stormwater Management



Source: Adapted from the Minnesota Stormwater Manual, 2005

available for wash-off. Even though we know that we will never be able to fully accomplish either of these goals, we can make substantial progress using the better site design techniques shown in Chapter 4 and the pollution prevention, volume minimization, temporary construction erosion control and supplemental techniques presented in Chapter 8.

After all of the efforts possible are made to minimize runoff and surface wash-off, we must recognize that some potential for runoff will occur. The next major BMP then becomes collection and treatment of runoff locally and regionally, either as stand-alone practices or in treatment train combinations. Finally, efforts at the level of the receiving water or for emergency overflow are at the tail end of the treatment train in the NWA. Some of the available BMPs are best used to reduce runoff volume, while others focus on water quality improvement. Some BMPs will be easier to implement, while others involve more detailed engineering evaluation and design. Chapter 8 presents detailed design guidance for categories of structural BMPs: bioretention devices, filtration practices, infiltration practices, stormwater ponds and stormwater wetlands.

Introduction to BMPs

This section introduces the Designer to the BMPs that are recommended for the Northwest Area. These BMPs are arranged in the following three categories:

- Non-structural or planning level BMPs;
- Structural BMPs; and
- Supplemental pre- and post-treatment BMPs.

As mentioned previously, additional design and construction information for these BMPs can be found in Chapter 8 of this Manual. Chapter 8 includes detailed BMP fact sheets on bioretention, filtration, green roofs, infiltration, pervious surfaces, rainwater harvesting, soil amendments, stormwater ponds and wetlands. Pollution prevention, runoff minimization and temporary construction runoff control practices will include some descriptive language for the numerous practices listed via “fact sheets,” but will not contain engineering details. The final section on treatment supplements will similarly not contain detailed engineering, but will describe a process that designers should follow when considering the use of proprietary devices, inserts and chemical/ biological treatment.

Non-Structural or Planning Level BMPs

The first level of BMP application occurs at the planning stage and is intended to minimize the impact of development. These practices are intended to prevent pollution and minimize the increase in stormwater volume and are considered prior to initiation of construction or land altering activity.

1. **Better Site Design/Runoff Volume Minimization -** Refer to Chapter 4

2. **Pollution Prevention Practices (Water Quality Focus)**

- Residential, municipal and industrial/commercial practice categories
- Specific recommended practices include such things as:
  - Housekeeping including landscaping, street sweeping, snow management, pavement maintenance, catch basin maintenance, yard waste reduction and litter control
  - Atmospheric controls including wind erosion and dust, as well as regulatory emission regulations
  - Chemical control of hazardous waste and salt, fertilizer/pesticides, spills (including prevention), swimming pool drainage
  - Animal waste management
  - Public works activities including chemical and sanitary wastes, and sewer maintenance

3. Temporary Construction Sediment Control (Water Quality Focus)
These practices are described in terms of perimeter, slope, drainageway and "other" criteria, and include:

- Vegetated buffers
- Silt fence
- Access/egress and drainage inlet protection
- Soil and slope stabilization
- Exposed soil covers and reinforcement

Structural BMPs (On Site/Local Treatment and Regional Treatment)

These BMPs have design guidance describing the engineering details for the BMP category. This design guidance is used, for example, to size BMPs to function effectively and with the least amount of maintenance. Also note that some of these BMPs, such as bioretention, can be used either as a volume reduction technique to meet the 5-year volume requirement or used for pre-treatment into another BMP.

4. Green Roofs. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention. Green roofs involve growing plants in an engineered soil on roof tops. Two types of green roofs are:

- Extensive
- Intensive

5. Rainwater Harvesting. Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. The two main types of rainwater harvesting are:

- Rain barrels
- Cisterns

6. Pervious Surfaces. Pervious pavements reduce the amount of stormwater runoff generated on a site by allowing water to pass through surfaces that would otherwise be impervious. The most common types of pervious surfaces are:

- Porous Pavement
- Pervious Pavers
- Reinforced Soils

7. Filtration. Filtering practices have widespread applicability and are suitable for all land uses, as long as the contributing drainage areas are limited.

- Media (sand) filters (surface, underground, perimeter/Delaware filter)
- Surface (vegetative) flow (grass channels, dry or wet swales, filter strips)
- Combination media/vegetative filters

8. Bioretention. This BMP suite includes vegetated systems that provide a combination of filtration and infiltration into a bio-system consisting of plants and soil, including:

- Rain gardens
- Depressed parking lot/traffic islands

- Road medians
- Tree pits/stormwater planters

9. Infiltration. Stormwater infiltration practices capture and temporarily store stormwater before allowing it to infiltrate into the soil.

- Trenches
- Basins
- Dry wells
- Underground systems

10. Stormwater Ponds. Design based upon components needed to fulfill the desired function.

- Components include forebay/pretreatment, various storage volumes, physical configuration
- Functions include water quality (including thermal impact) and flow control (rate and volume), which determine whether they are wet/dry or some combination

11. Constructed Wetlands. Selection criteria is similar to stormwater ponds.

- Components include pre-treatment, various storage volumes (detention needed), biologic character
- Functions include primarily water quality and flow control, but could also include ecological factors

12. Soil Amendments. Soil amendments repair soil structure and restore the soil's ability to filter/infiltrate stormwater and produce healthier plants. Soil structure can be preserved by:

- Protecting native soils in-place
- Amending existing soils with compost
- Importing topsoil to amend graded soils
- Stockpiling topsoil and duff and reapplying post-grading activities (only applicable to sites that have original, undisturbed native topsoil)
- Stockpiling topsoils, reapplying and amending after construction

Supplemental Pre- and Post-Treatment BMPs

The final category of BMPs are those that are generally, but not always, included in the stormwater treatment train as a supplement to the primary treatment device. These are described in less detail than the previous sections. The designer will be guided through a process of determining the function a generic device serves within the treatment train and evaluating the proposed device against the needed function and manufacturer claims. Proprietary devices are generically described rather than listed as individual companies to avoid omission and claims of certification in the Manual.

13. Supplemental Pre- and Post-Treatment.

- Hydrodynamic
  - Proprietary sediment and oil/grease removal devices
  - Wet vaults
  - Skimmers

- Filtration
  - Catch basin inserts
  - Sorbents
  - Proprietary filtration devices

- Chemical/biological treatment
  - Chemical treatment * (ferric chloride, alum, polyacrylamides)
  - Biological additives (ex. chitosan)

    * Note that these chemical treatments could be limited in the State of Minnesota because of the potential toxic effects associated with them; care will be taken to assess these impacts in the BMP discussion.

III. Process for Selecting Best Management Practices

Designers need to carefully think through many factors to choose the most appropriate, effective and feasible practice(s) at a development site that will best meet the City's stormwater objectives. This chapter presents a flexible approach to BMP selection that allows a stormwater manager to select those BMPs most able to address an identified problem. Selecting an inappropriate best management practice (BMP) for a site could lead to adverse resource impacts, friction with regulators if a BMP does not work as anticipated, misperceptions about stormwater control success, and wasted time and money. Careful selection of BMPs will prevent the negative impacts of installing the wrong BMP at the wrong location. City staff can similarly use the BMP selection matrix (Table 5.8) to check on the potential efficiency of proposed BMPs.

Seven factors should be evaluated in the BMP selection process, as follows:

1. Investigate Pollution Prevention Opportunities. Evaluate the site to look for opportunities to prevent pollution sources on the land from becoming mobilized by runoff.

2. Design Site to Minimize Runoff. Determine which better site design techniques are required per the PUD and which additional techniques can be applied at the site to minimize runoff and therefore reduce the size of structural BMPs.

3. Select Temporary Construction Sediment Control Techniques. Check to see what set of temporary sediment control techniques will prevent erosion and minimize site disturbance during construction.

4. Identify Downstream Issues. Understand the context of the receiving water, landlocked basin, or downstream area to which the site drains. Depending on the conditions present in this area, certain BMPs may be promoted, restricted or prohibited, or special design or sizing criteria may apply.

5. Evaluate Stormwater Treatment Suitability. Not all BMPs will be able to mitigate the pre- and post-development difference in runoff volume for the 5-year 24-hour rainfall event so designers need to choose the type or combination of BMPs that will provide the desired level of treatment.

6. Assess Physical Feasibility at the Site. Each development site has physical constraints that influence the feasibility of different kinds of BMPs; designers confirm feasibility by assessing eight physical factors at the site.

7. Determine Any Site Restrictions and Setbacks. Check to see if any environmental resources or infrastructure are present that will influence where a BMP can be located at the development site.

These factors are described in more detail below.

Investigate Pollution Prevention Opportunities

Pollution prevention should be the first consideration during any development or redevelopment project. This step involves looking for opportunities to reduce the exposure of soil and other pollutants to rainfall and possible runoff.

Examples of pollution prevention practices include keeping urban surfaces clean, proper storage and handling of chemicals, and preventing exposure of unprotected soil and pollutants. More information on pollution prevention practices can be found in Chapter 8 of this Manual.

Design Site to Minimize Runoff

A range of better site design (BSD) techniques are described in Chapter 4 of this Manual. These can provide non-structural stormwater treatment, improve water quality and reduce the generation of stormwater runoff. These techniques reduce impervious cover and reduce the volume of stormwater runoff at a site, which can save space and reduce the cost of structural BMPs.

Select Temporary Construction Sediment Control Techniques

Construction sites can be a major source of sediment and nonpoint source pollutants if soils are exposed to erosion. Effective application of temporary sediment controls is an essential element of a stormwater management plan and helps preserve the long-term capacity and function of permanent stormwater BMPs. Designers should recognize that they will need to revisit and refine the erosion and sediment control plan throughout the design and construction period as more information on site layout and the type and location of BMPs becomes available.

Table 5.1 lists the range of temporary erosion and sediment control techniques that could be considered in the erosion and sediment control plan for a site. The table indicates how each technique reduces erosion and sediment transport, when it is applied in the construction process, and provides some additional comments. More information on how to integrate erosion and sediment control in the context of site design is discussed in Chapter 4 of this Manual. More detailed design guidance on erosion and sediment control techniques can be found in Chapter 8 and *Protecting Water Quality in Urban Areas* (MPCA, 2000).

Table 5.1 Temporary Construction Erosion and Sediment Control Techniques

Technique	Practice	Application Benefit	When to Apply	Comments
Pre-construction	Site planning and grading	Minimizes soil disturbance and unprotected exposure	Planning	Expose only as much area as needed for immediate construction. The City requires a stormwater management plan be submitted with all permit applications. PUD requires staged construction and control techniques to preserve infiltration capacity at site and regional facilities. NPDES general permit for construction requires development of a Stormwater Pollution Prevention Plan (SWPPP) for projects disturbing >1 acre or part of a larger common development plan.
	Sequencing	Limits amount of soil exposed	Planning	
Resource protection	Wetland Buffers and Natural Areas Open Space	Establishes protective zone around valued natural resources	Early	Wetland buffer variable from 16-50 feet depending upon wetland management standard (see Table 5.2). PUD requires minimum of 20% of net developable area to be designated as Natural Area/Open Spaces at least 100 feet wide.

Table 5.1 Temporary Construction Erosion and Sediment Control Techniques

Technique	Practice	Application Benefit	When to Apply	Comments
Perimeter controls	Access and egress control	Minimizes transport of soil off-site	Early	Must be in place prior to commencement of construction activities. Section 420 of City Code requires fencing completely around the site when open excavation exceeds 20 feet and/or a slope of 2:1 or greater
	Inlet protection	Stops movement of soil into drainage collection system	Early	
Slope stabilization	Grade breaks	Minimizes rill and gully erosion	Early	NPDES general permit for construction requires no unbroken slopes > 75 ft. on 3:1 or steeper slopes
	Silt curtain	Stops sediment from moving	Early	
Runoff control	Stabilize drainageways	Minimizes increased erosion from channels	All construction phases	Possible to convert these into permanent open channel systems after construction
	Sediment control basins	Collects sediment that erodes from site before it leaves site or impacts resource	All construction phases	City code requires if site has larger than 10 acres disturbed at one time that sediment control basin(s) be constructed. Possible to convert these into post construction practices after construction

Table 5.1 Temporary Construction Erosion and Sediment Control Techniques

Technique	Practice	Application Benefit	When to Apply	Comments
Rapid stabilization of exposed soils	Seeding and mulch	Immediately establishes vegetative cover on exposed spoil	All construction phases	Apply seed as soils are exposed and blankets on steep slopes or as needed to control erosion until plants are established. City code requires all disturbed ground left inactive for 14 or more days to be stabilized. City code requires topsoil and turf reestablishment within twelve months of the issuance date of the building permit or as defined in land alteration permit.
	Blankets	Provides extra protection for exposed soil or steep slopes	All construction phases	
Inspection and maintenance	Formalized I&M program	Assures that BMPs are properly installed and operating in anticipated manner	All construction phases	Essential to proper BMP implementation. PUD requires: license contract allowing City inspections at any time, public easements for maintenance access, and covenants or maintenance agreements for all facilities not maintained by the City.

Identify Downstream Issues

The receiving surface waters in the NWA consist of landlocked wetlands and lakes. Given the landlocked nature of the area and the City's volume control standard, an indirect receiving water that must also be taken into consideration is the groundwater system. Designers should understand the nature and regulatory status of the waters that will receive runoff from the development site. The type of receiving water can influence the preferred BMP to use, and in some cases, may trigger increased treatment requirements. In general, all stormwater BMPs should be located outside of the shoreline and/or wetland buffer and they should be setback from wells and septic systems.

► **Does the site drain to a wetland?**

Wetlands can be indirectly impacted by upland development sites, so designers should choose BMPs that can maintain wetland hydroperiods and limit phosphorus loads.

The wetland types found in the NWA are identified in the Natural Wetland Resource Inventory (NRI) Report (2004). The NRI also assigns management classifications based on the susceptibility of these wetland types to stormwater impacts ranging from 1 (high susceptibility to stormwater bounce) to 4 (low susceptibility to stormwater bounce). This report also provides recommended buffer widths and stormwater quantity requirements based on the wetland classifications. Table 5.2 summarizes the wetland management standards adopted for the NWA.

Table 5.2 Wetland Management Standards

Management Classification	Buffer Strip (feet)	Structural Setback from Edge of Buffer (feet)	Stormwater Quantity Requirement
Manage 1	60	10	Storm Bounce - Maintain HWL at or below existing conditions for 100-year storm
Manage 2	30	10	Storm Bounce - Maintain HWL at or below existing conditions plus 0.5 feet for 100-year storm
Manage 3	20	10	no requirement
Manage 4	15	10	no requirement

Of the wetlands delineated in the Northwest Area, 16 would realize a storm bounce that exceeds the recommended stormwater quantity requirement even with the 5-yr volume control standard implemented. In order to prevent this undesired bounce, a higher stormwater management standard (or additional stormwater management storage) is required within these subwatersheds upstream of the existing wetlands.

Table 5.3 should be used to identify any wetlands on your site that will need further volume reductions beyond the 5-yr volume control standard. Detailed site modeling for post development conditions with

all BMPs and LID in place may show more or less infiltration volume requirement than identified in the table. Stormwater modeling including all BMPs should be completed to demonstrate that the wetlands will not exceed the bounce criteria. Site plans and modeling will be reviewed by the city to ensure that the final design meets the stormwater quantity requirement for wetland management.

Table 5.3 Wetlands that Exceed the Stormwater Quantity Requirement

Subwatershed Name	NRI - Management Class	Excess Bounce Above Recommendation (feet)	Protection Method	Special Volume Control Standard (in. above 5-year standard)	Special Volume Control Standard (ft^3 above 5-year standard)
BP-032	2	0.2	Higher Standard	0.4	15650
EP-010b	2	0.8	Higher Standard	0.5	58820
EP-013	2	0.9	Higher Standard	0.5	79199
EP-016b	2	0.2	Higher Standard	0.4	20446
EP-027f	2	0.2	Higher Standard	0.7	15085
EP-031b	1	0.1	Higher Standard	0.3	14537
EP-039	2	0.6	Higher Standard	0.4	56224
EP-060b	2	0.4	Higher Standard	0.5	42719
EP-071	1	2.7	Regional Basin	None	390299
EP-073a	1	2.7	Regional Basin	None	152519
EP-080a	1	0.3	Higher Standard	0.7	336195
EP-080b	1	0.4	Higher Standard	0.6	37906
F-001	1	1.2	Regional Basin	None	56142
F-002	2	0.2	Higher Standard	0.4	9597
F-025	1	0.5	Higher Standard	1.2	333438
SP-16	1	0.6	Higher Standard	0.5	35416

Most developing areas will see a decrease in upland depressional storage (storage naturally present in un-graded landscapes) which will be mitigated with infiltration BMPs and LID techniques. Three wetlands will likely see major losses of depressional storage available in their watersheds, F-001, EP-073a, and EP-071. For these watersheds (and potentially others) developers would be especially well served to maintain or enhance some of these low-lying features as larger regional infiltration areas.

► **Does the site drain to a lake?**

Existing statewide minimum shoreline standards affect lakes in the NWA. These standards set guidelines for the use and development of shoreland property, including a sanitary code, minimum lot size, minimum water frontage, building setbacks, building heights, and subdivision regulations.

Additionally, lakes in the NWA have wetland fringes that have been designated into wetland management categories in the NWI. See Table 5.4 and the previous section for additional information regarding these areas.

Designers should choose BMPs that limit sediment and nutrient loading into lakes (especially phosphorus).

Table 5.4 Lakes in the NWA and Wetland Fringe Management Categories		
Lake Name	**DNR Identifier**	**Wetland Fringe Management Category***
Dickman	19-46P	Manage 4
Hornbean	19-47P	Manage 4
Marcott	19-41P	Manage 1
Unnamed	19-36P	Manage 4
Unnamed	19-54P	Manage 1
*For more information on these management categories see Table 5.2 or the NRI Report (BRAA, 2004).		

► **Is the site within a ground water drinking water source area?**
Sites located in aquifers used for drinking water supply require BMPs that can recharge aquifers at the same time they prevent ground water contamination from polluted stormwater, particularly when it is generated from potential stormwater hotspots (PSH).

Evaluate Stormwater Treatment Suitability

Not all BMPs will be able to meet the City's stormwater management standards on their own. Designers first need to determine which of the stormwater management requirements (i.e. volume control, peak discharge, pretreatment requirements, wetland bounce and duration) apply to the development site (see Table 5.5) and then choose the type or combination of BMPs that can be used to achieve them.

This is the stage in BMP selection process where designers often find that a single BMP may not satisfy all stormwater treatment requirements. The alternative is to use a combination of BMPs arranged in a series or treatment train, or add supplemental practices to the primary BMP that provide additional pre- or post-treatment.

► **Can the BMP provide volume control?**
BMPs that infiltrate runoff into the soil will be needed to meet the City's volume control standard. Designers may want to use some of the better site design techniques presented in Chapter 4 to reduce the volume of stormwater runoff generated under post-development conditions.

► **Can the BMP be used to satisfy the pretreatment requirements of other BMPs?**
Pretreatment is required to protect the BMP from clogging and groundwater contamination that may occur. Some BMPs may also be used to satisfy the pretreatment requirements for other BMPs. See Chapter 7 for more details on pretreatment requirements.

► **Can the BMP effectively control peak discharges?**
Generally, only ponds, wetlands and infiltration basins have the capacity to control peak discharge events that cause flooding at the site (e.g., 10-year 24-hour and 100-year 24-hour storm events). Once again, if a BMP cannot meet peak discharge requirements, it can be used in combination with one that does to meet all sizing criteria.

► **Can the BMP accept runoff from potential stormwater hotspots (PSHs)?**
Designers may need to give more consideration to the selection of BMPs at sites designated as PSHs since the land use and associated on-site activities have the potential to generate higher pollutant runoff loads compared to other land uses. A more detailed discussion on PSHs can be found in Chapter 6.

Table 5.5 Stormwater Treatment Suitability for Selected BMPs					
BMP Group		**Volume Control**	**Used for Pre-treatment**	**Peak Discharge**	**PSH**
Bioretention		Varies[1]	Varies[2]	Yes	Varies[2]
Filtration	Surface	Varies[1]	Yes	Yes	Yes
	Under-ground	No			
Infiltration	Trench	Yes	No	Yes	Yes, additional pretreatment requirements
	Basin			Yes	
Ponds		No[2]	Yes	Yes	Yes
Wetlands		Varies[2]	No	Yes	Yes, additional pre-treatment requirements
Supplemental BMPs		Varies	Yes	No	Yes

[1] May be provided by infiltration
[2] When impermeable liners are required or pool intercepts groundwater

Assess Physical Feasibility at the Site

By this point, the list of possible BMPs has been narrowed and now physical factors at the site are assessed to whittle it down even further. Table 5.6 indicates eight physical factors at the site that can constrain, restrict or eliminate BMPs from further consideration.

- **Is there enough space available for the BMP at the site?**
  BMPs vary widely in the amount of surface area of the site they consume, which can be an important factor at intensively developed sites where space may be limiting and land prices are at a premium. In some instances, underground BMPs may be an attractive option in highly urban areas. Some general rules of thumb on BMP surface area needs are presented in Table 5.6, expressed in terms of contributing impervious area or total area.

- **Is the drainage area at the site suitable for the proposed BMP?**
  Table 5.6 shows the minimum or maximum recommended drainage areas for each group of BMPs. If the drainage area of the site exceeds the maximum, designers can consider subdividing the drainage area and/or use multiple smaller BMPs of the same type, or modify the design. The minimum drainage area thresholds for ponds and wetlands are not quite as flexible, although smaller drainage areas can work if designers can confirm the presence of ground water or baseflow that can sustain a normal pool and incorporate design features to prevent clogging.

- **Will soils limit BMP options at the site?**
  Low infiltration rates limit the use of infiltration practices and certain kinds of bioretention designs. Designers should consult the design guidance in Chapter 8 to determine minimum soil infiltration rates and testing procedures for each kind of BMP. Table 5.6 references USDA-NRCS Hydrologic Soil Groups A to D. Further geotechnical testing may be needed to confirm soil permeability and depth to ground water. The designer should strive to locate BMPs on those portions of the site with the most permeable material and situate the building/impervious surfaces on the least permeable portions of the site.

Table 5.6: Physical Feasibility of the Site

BMP Group		Surface Area[1]	Drainage Area	Soils Infiltration Rate[5]	Head	Separation from Bedrock	Depth to Seasonally High Water Table	Max. Slope[3]	Ultra-Urban
Bioretention		7-10% Min 200 ft^2	5 ac max 0.5-2 ac preferred	Any soil. Use underdrain in C, D [4]	1-4 ft	3 ft	3 ft	20%	Yes
Filtration	Surface	Varies based on depth	10 ac max	media part of design[4]	2-6 ft	0 ft if enclosed	3 ft for vegetated; 0 ft if enclosed	20%	Possible
Filtration	Under-ground	Negligible, except for access	5 ac max 0.5-2 ac preferred	media part of design[4]	2-6 ft	0 ft if enclosed	3 ft for vegetated; 0 ft if enclosed	20%	Yes
Infiltration	Trench	Varies based on depth	5 to 10 ac max	Any soil.	2-12 ft	Min. 3 ft	Min. 3 ft	15%	Possible
Infiltration	Basin	Varies based on depth	5-50 ac max	Any soil.	2-12 ft	Min. 3 ft	Min. 3 ft	15%	No
Ponds		1-3%	25 ac min^2	A or B soils may require liner	3-10 ft	0 ft (shallow soil limits design)	0 ft (except if hotspot or aquifer)	25%	No
Wetlands		2-4%	25 ac min^2	A or B soils may require liner	3-10 ft	0 ft	0 ft (except if hotspot or aquifer)	25%	No

Table 5.6: Physical Feasibility of the Site

BMP Group	Surface Area[1]	Drainage Area	Soils Infiltration Rate[5]	Head	Separation from Bedrock	Depth to Seasonally High Water Table	Max. Slope[3]	Ultra-Urban
Green Roofs	Up to 100%	Any	Engineered Soils	NA	NA	NA	30%	Yes
Pervious Pavements	Up to 100%	Any	Any soil. Use underdrain in C, D [4]	NA	3 ft	3 ft	2%	Yes
Rainwater Harvesting	0-2%	Dependant on Application	Any soil.	NA	NA	NA	None	Yes
Soil Amendments	Up to 100%	Any	Any Soil	NA	NA	NA	None	Yes

[1] Surface area as a function of contributing impervious area, except for ponds and wetlands, where it is a function of entire drainage area.

[2] 10 acres may be feasible if groundwater is intercepted and/or if water balance calculations indicate a wet pool can be sustained.

[3] Slope is defined as the slope across the proposed location of the practice

[4] Infiltration gallery could be designed to provide limited recharge

[5] If infiltration practice being used to meet IGH standards ensure that it meets the 72-hour drawdown requirement.

- **Is enough head present at the site to drive the BMP?**
  Head is defined as the elevation difference between the inflow and outflow point of a BMP that enables gravity to drive the BMP.

- **Will depth to bedrock or the water table constrain the proposed BMP?**
  Bioretention, infiltration and some filtering practices need a minimum separation distance from the bottom of the practice to bedrock (or the water table) to function properly. The Minnesota Pollution Control Agency's Construction General Permit (CGP) requires a minimum distance of three feet between the bottom of an infiltrating BMP and the seasonally saturated water table. Other BMPs do not require as much separation distance, although the cost and complexity of construction of most BMPs increases sharply at development sites where the bedrock or water tables are close to the surface.

- **Is the slope at the proposed BMP site a design constraint?**
  Sites with extremely steep slopes can make it hard to locate suitable areas for BMPs. Table 5.6 outlines maximum slope recommendations for BMPs, which refers to the gradient where the BMP will actually be installed. Designers will need to carefully scrutinize site topographic and grading plans to find suitable locations, and if this does not work, the grading plan may need to be changed to meet slope thresholds.

- **Is the BMP suitable for ultra-urban sites?**
  BMP selection for ultra-urban development and redevelopment sites is challenging, since space is extremely limited, land is expensive, soils are disturbed, and runoff volumes and pollutant loadings are great. These sites do, however, present a great opportunity for making progress in stormwater management where it has not previously existed. Table 5.6 compares the general suitability of BMPs for ultra urban sites.

Determine Any Site Restrictions and Setbacks

The last step in BMP selection checks to see if any environmental resources or infrastructure are present that will influence where a BMP can be located on the site (i.e., setback or similar restriction). Table 5.7 presents an overview of the site-specific conditions that impact where a BMP can be located on a site.

Table 5.7 Restrictions and Setbacks

Factor	Considerations
Jurisdictional Wetland U.S Army Corps of Engineers (USACE) Section 404 Permit And Minnesota Department of Natural Resources And Local Governments under the Wetland Conservation Act	► Wetlands should be delineated prior to siting stormwater BMPs. Demonstrate that the impact to a wetland complies with all of the following principles in descending order of priority: avoid direct or indirect impacts, minimize impact by limiting the degree or magnitude of activity, replace unavoidable impacts through restoration or creation ► Always check with local, state and federal jurisdictions for appropriate regulations ► Natural wetlands should not be used for stormwater treatment, unless they are severely impaired, and construction would enhance or restore wetland functions. ► Direct pipe outfalls to wetlands should be restricted. The discharge of untreated stormwater to a wetland should be avoided. ► BMPs are restricted in the wetland buffer. ► For sensitive bogs and fens, BMPs should be designed for site-based nutrient load reduction. ► The Wetland Conservation Act applies to wetlands that do not fall under DNR (Public Waters) or USACE.

Table 5.7 Restrictions and Setbacks	
Factor	**Considerations**
Shoreland Management DNR and Local Governments State Floodplain Management Act	► Check state and local shoreland development ordinances regarding BMP setbacks from the shoreline and any required buffers
100-year Floodplain	► Grading and fill for BMP construction is strongly discouraged within the ultimate 100-year floodplain, as delineated on FEMA flood insurance rate maps, FEMA flood boundary and floodway, or more stringent local maps. ► Floodplain fill cannot raise the 100-year water surface elevation by more than a tenth of a foot.
Water Wells - private and municipal	► Observe local wellhead protection zones and minimum setbacks. ► Consult the Minnesota Department of Health, County health department and local water utility. ► MN DOH Rule 4725.4350 requires a 50 foot setback between stormwater ponds and water supply wells ► If not otherwise regulated, a similar 50 foot setback for infiltration BMPs is advisable ► No infiltration of confirmed stormwater hotspot runoff. Infiltration of potential stormwater hotspot (PSH) runoff should be restricted and have suitable pretreatment
Septic Systems	► Recommended setback is 35 feet minimum from a drain field. ► Consult the Minnesota Department of Health and County health department.
Utilities	► Call the **Gopher State One** to locate existing utilities prior to design. ► Consider the location of proposed utilities to serve the development. ► Structural controls are discouraged within utility easements or the right of way for public or private utilities.
Roads	► Consult local/county highway or public works department for any setback requirement from local/county roads. ► Consult MNDOT guidelines for setback from State roads. ► Approval may be needed to discharge stormwater to a local, county or state owned storm drain or channel.
Structures	► Consult the local review authority for the BMP setback from structures. ► Recommended setbacks for each BMP group are provided in Chapter 8 of this manual.

IV. BMP Selection Matrix

Table 5.8 is a BMP selection matrix that can be used as a guide for the identification of suitable BMPs for a particular application.

Table 5.8 Best Management Practices Matrix

	Non-Structural or Planning Level BMPs										Structural BMPs (On-Site/Local Treatment and Regional Treatment)																		Supplemental Pre- and Post-Treatment BMPs		
	Better Site Design	Pollution Prevention			Temporary Construction Sediment Control						Green Roofs	Rain-water Harvest	Pervious Surfaces	Filtration		Bioretention				Infiltration				Storm-water Ponds		Constructed Wetlands			Soil Ammend-ments	Supplemental Treatment		
Use Assessment Parameter (see Chapter 7 for details of parameter)	See Chapter 4 for Techniques	Residential	Municipal	Industrial/Commercial	Pre-Construction	Perimeter	Slope	Drainageway	Other [2]	Inspect/maintain	Extensive/Intensive	Rain Barrels/Cisterns	Porous Pavements, Permeable Pavers and Reinforced Soil	Media (sand)	Vegetative	Infiltration/recharge	Filtration/partial recharge	Infiltration/filtration/recharge	Filtration	Infiltration Basin	Infiltration Trench	Dry Well	Underground System	With Extended Detention	Without Extended Detention (ex. Walker Pond)	Shallow Wetland	ED Shallow Wetland	Pond/wetland System		Chem./Biological Treatment	Filtration devices	Hydrodynamic Devices
1. Pollution Prevention	●	●	●	●	●	●	●	●	●	●					◐				◐												
2. Design to Minimize Runoff [3]	●													◐	◐	●	●	●	◐	●	●	●	●			◐	◐	◐	●			
3. Temporary Construction Sediment Control			●	●	●	●	●	●	●	●			○	●	●	◐	◐	◐	●	○	○	○	○	●	●	◐	◐	●		◐	●	●
4. Identify Downstream Uses																																
- Wetland	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	◐	◐	●	●	●		
- Lake	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		

Table 5.8 Best Management Practices Matrix

	Non-Structural or Planning Level BMPs										Structural BMPs (On-Site/Local Treatment and Regional Treatment)																	Supplemental Pre- and Post-Treatment BMPs		
	Better Site Design	Pollution Prevention			Temporary Construction Sediment Control						Green Roofs	Rain-water Harvest	Pervious Surfaces	Filtration		Bioretention				Infiltration				Storm-water Ponds		Constructed Wetlands			Soil Ammend-ments	Supplemental Treatment		
Use Assessment Parameter (see Chapter 7 for details of parameter)	See Chapter 4 for Techniques	Residential	Municipal	Industrial/Commercial	Pre-Construction	Perimeter	Slope	Drainageway	Other[2]	Inspect/maintain	Extensive/Intensive	Rain Barrels/Cisterns	Porous Pavements, Permeable Pavers and Reinforced Soil	Media (sand)	Vegetative	Infiltration/recharge	Filtration/partial recharge	Infiltration/filtration/recharge	Filtration	Infiltration Basin	Infiltration Trench	Dry Well	Underground System	With Extended Detention	Without Extended Detention (ex. Walker Pond)	Shallow Wetland	ED Shallow Wetland	Pond/wetland System		Chem./Biological Treatment	Filtration devices	Hydrodynamic Devices
5. Evaluate SW Treatment Suitability																														
- Volume Control	●						◐	◐	◐		●	●	●		◐	●	●	●	◐	●	●	●	●						●			
- Pretreat-ment	●	●	●	●		●	●	●	●	●			○	●	●	○	○	○	●	○	○	○	○	●	●	●	●	●	●	●	●	●
- Peak discharge			●				●		◐		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
- PSH[3]	◐	●	●	●									◐	●	◐	◐	◐	◐	◐	◐	◐	◐	◐	●	●	●	●	●				
6. Assess Physical Feasibility at the Site[4]																														
- Limited Space Availability	●	●	●	●																										◐	◐
- Drainage area																									○	○	○				

Table 5.8 Best Management Practices Matrix

	Non-Structural or Planning Level BMPs										Structural BMPs (On-Site/Local Treatment and Regional Treatment)																	Supplemental Pre- and Post-Treat-ment BMPs		
	Better Site Design	Pollution Prevention			Temporary Construction Sediment Control						Green Roofs	Rain-water Harvest	Pervious Surfaces	Filtration		Bioretention				Infiltration				Storm-water Ponds		Constructed Wetlands			Soil Ammend-ments	Supplemental Treatment		
Use Assessment Parameter (see Chapter 7 for details of parameter)	See Chapter 4 for Techniques	Residential	Municipal	Industrial/Commercial	Pre-Construction	Perimeter	Slope	Drainageway	Other[2]	Inspect/maintain	Extensive/Intensive	Rain Barrels/Cisterns	Porous Pavements, Permeable Pavers and Reinforced Soil	Media (sand)	Vegetative	Infiltration/recharge	Filtration/partial recharge	Infiltration/filtration/recharge	Filtration	Infiltration Basin	Infiltration Trench	Dry Well	Underground System	With Extended Detention	Without Extended Detention (ex. Walker Pond)	Shallow Wetland	ED Shallow Wetland	Pond/wetland System		Chem./Biological Treatment	Filtration devices	Hydrodynamic Devices
- Soils Infiltration Rate						●	●	●						●	●				●	○	○	○	○			◐	◐					
- Head							◐												●													
- Depth to water table/ bedrock	●													●	●	○	○	○	●	○	○	○	○	○	○	●	●					●
- Slope	●					●	●	●								◐	◐	◐	◐													
- Ultra-urban land use	●	●	●			●	●							●	●	●	●	●	●				●	○	○	○	○	○			●	●

● = Recommended
◐ = Recommended with conditions (see Chapter 8)
○ = Not recommended;
Empty space = neutral

[1] See Chapter 8 descriptions
[2] Other includes drainage inlets, trees, and waterbodies
[3] PSH = "potential stormwater hotspot"
[4] See Table 5.6

V. References

Caraco, D. 2001. "Managing Phosphorus Inputs Into Lakes III: Evaluating the Impact of Watershed Treatment." Watershed Protection Techniques. 3(4): 791-796. Center for Watershed Protection. Ellicott City, MD.

Maryland Department of the Environment (MDE). 2000. 2000 Maryland Stormwater Design Manual. MDE. Baltimore, MD.

Minnesota Department of Transportation, 2005. The Cost and Effectiveness of Stormwater Management Practices. Report 2005-23, St. Paul, MN.
http://www.lrrb.org/pdf/200523.pdf

Walker Jr., W. W., 2000. P8 Urban Catchment Modal (Version 2.4), IEP, Inc. and Narrangansett Bay Project USEPA/RIDEM.
http://www.wwwalker.net/p8/

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

INVER GROVE HEIGHTS
Northwest Area

Chapter 6

Additional Design Considerations

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Additional Design Considerations

Chapter 6

Key Topics: cold climate considerations, cold climate challenges for BMP engineering and design, potential stormwater hotspots (PSH), ground water, mosquitoes

Contents

I. Introduction..... 3
II. Cold Climate..... 3
III. Potential Stormwater Hotspots (PSHs)..... 20
IV. Mosquito Control..... 26
V. References..... 28

I. Introduction

The objective of this chapter is to raise the design engineer's awareness about certain factors that could affect the performance of best management practices (BMPs). These factors include:

- ► Cold Weather Design Considerations
- ► Potential Stormwater Hotspots (PSHs)
- ► Mosquito Control

How the design engineer decides to modify a BMP to address these factors depends on the site and the particular application of the BMP. Discussion of each of these factors will include an introduction to the issue, key points to consider in designing BMPs and suggestions for addressing these points. Ultimately, it will be up to the design engineer to determine the most suitable means for addressing these design considerations given the specifics of the site and their application.

II. Cold Climate

This section presents the latest national and international findings on stormwater management practices maintained in cold climate regions. It presents principles for adapting BMPs to provide effective pollutant removal and runoff control during cold weather months. Specific cold climate adaptations for specific BMPs are presented in callout boxes and are reiterated in Chapter 8 of the Manual.

The Designer must recognize that runoff from snowmelt has characteristics different from those of rainfall runoff, and that BMP design criteria addressing only rainfall runoff might not work well during cold periods. This can become a problem because a substantial percentage of annual runoff volume and loading can come from snowmelt in years when snowfall is high.

Nature of the Cold Climate Problem

Hydrology of Melt

The heart of the problem with snowmelt runoff is that water volume in the form of snow and ice builds for several months and suddenly releases with the advent of warm weather in the spring or during short interim periods all winter long. The interim melts generally do not contribute a significant volume of runoff when compared to the large spring melt. Snowmelt peaks are substantially less than those from rainfall, but the total event volume of a snowmelt, although it occurs over a much longer period, can be substantially more. Factors influencing the nature of this melt and the speed with which it occurs include solar radiation, the distribution of snow cover, the addition of de-icing chemicals to the pack, and the amount of freeze-thaw cycling. Ignoring the contribution of these large spring melts to the annual runoff and pollution loading analysis could be a major omission in a watershed analysis. This illustrates why facility design is critical to the proper quantity and quality management of this meltwater.

Three areas play roles in both the hydrologic and water quality character of snowmelt runoff.

1. Roadways and large paved surfaces like commercial parking lots are the direct recipients of fast and efficient snow removal. Because of the need for sanding and salting to promote safety, numerous loading events are generated every time it snows, and often in anticipation of a snowfall since pre-icing application of salt can be a common practice.
2. Areas immediately adjacent to the roadway or parking surface are often recipient of snow plowed and piled in these areas, resulting in both equivalent water volume and pollutant accumulation for an extended period of time over the winter. This material is then available for release and migration over a several week period in the spring. Since this critical area is usually contained within about 25 feet of the paved surface it easily flows to the storm drain system as it melts.
3. Snowmelt from less developed residential, open space, and low-density areas typical of suburban watersheds can be large contributors of meltwater volume, but the quality of the melt is better

than from roadways and parking areas. Typically a fair amount of the initial meltwater soaks into the ground and can continue to do so as long as the rate of melt does not exceed the infiltration capacity of the soil. However, depending on ground frost conditions and snowpack availability, saturation can occur, leading to this portion of the watershed acting as an impervious surface.

Snowpack builds throughout the winter and increases in moisture content as the winter season draws toward melt. When meltwater exits the snowpack, it moves into the ground or over the land surface. It is very common for the first part of the melt to soak into the ground. However, at some point in the melt sequence, particularly when there is a deep snowpack at the on-set, the ground can become saturated and turn a pervious, non-contributing part of the watershed into an essentially impervious surface from which all additional melt runs off. Hydrographs from melt events will typically show a period of little to no runoff, even though the melt rate might be high, followed by accelerating flow as the ground no longer soaks in the melting snowpack.

The source area for snowmelt plays a critical role in both the hydrologic and water quality character of snowmelt runoff, as shown in Figures 6.1a through 6.1c. Roadways and large paved surfaces (Figure 6.1a) like commercial parking lots are the direct recipients of fast and efficient snow removal. This can occur by plowing, which can include total site removal or relocation off of the surface, and/or chemical-induced (salt) melting. Because of the need to promote safety, obtaining an ice and snow-free surface is a focal point for winter management of these surfaces. As a result, these surfaces generate numerous loading events every time it snows or even in anticipation of a snowfall, since pre-icing application of salt can be a common practice. By the time the major spring melt occurs, many of these surfaces are free of snow and ice. However, in many instances the snow that has been removed is piled or plowed close to the surface and flows onto it. At this time it becomes part of the urban drainage system or is stored in a location where it immediately enters the drainage system upon melt. These road and parking surfaces can be a significant source of many of the most contaminating pollutants associated with urban runoff.

Figure 6.1b shows the second category of importance to snowmelt runoff and the area that is generally the most significant source of poor water quality during a melt. This is the area immediately adjacent to the roadway or parking surface. Because snow is plowed and piled in these areas, they accumulate both equivalent water volume and pollutants for an extended period of time over the winter. This material is then available for release and migration over a several week period in the spring. This critical area is usually contained within about 25 feet of the paved surface and easily flows to the storm drain system as it melts. Sometimes, as in commercial parking or roadside piles, the snow is actually sitting on an impervious surface.

The final contributing area to meltwater runoff is the less developed residential, open space, low density area typical of suburban watersheds (Figure 6.1c). Snowmelt from these areas can be large contributors of meltwater volume, but the quality of the melt is better than from roadways and parking areas. Typically a fair amount of the initial meltwater soaks into the ground and can continue to do so as long as the rate of melt does not exceed the infiltration capacity of the soil. If sufficient snowpack is available, saturation can occur, leading to this portion of the watershed acting as an impervious surface.

Quality of Melt

Figure 6.2 illustrates the accumulation of surface material on a snowpack compared to that occurring on the same urban surface during the rainfall season. The material builds for several months prior to wash -off. Since snow is a very effective scavenger of atmospheric pollutants, any airborne material present in snow catchment will show up in meltwater when it runs off.

Part of the severity of the water quality problem associated with melt is that it occurs when the hydrologic system is least able to deal with it. This melting sequence becomes a very important part of snowmelt quality management because the practices we use may or may not come close to treating a particular target pollutant depending upon where in the sequence it is captured. Routine assumptions on biological

Figure 6.1a Direct Pave Surface with Heavy Traffic





Figure 6.1b Nearby Areas of Snow Accumulation from Distribution/Plowing





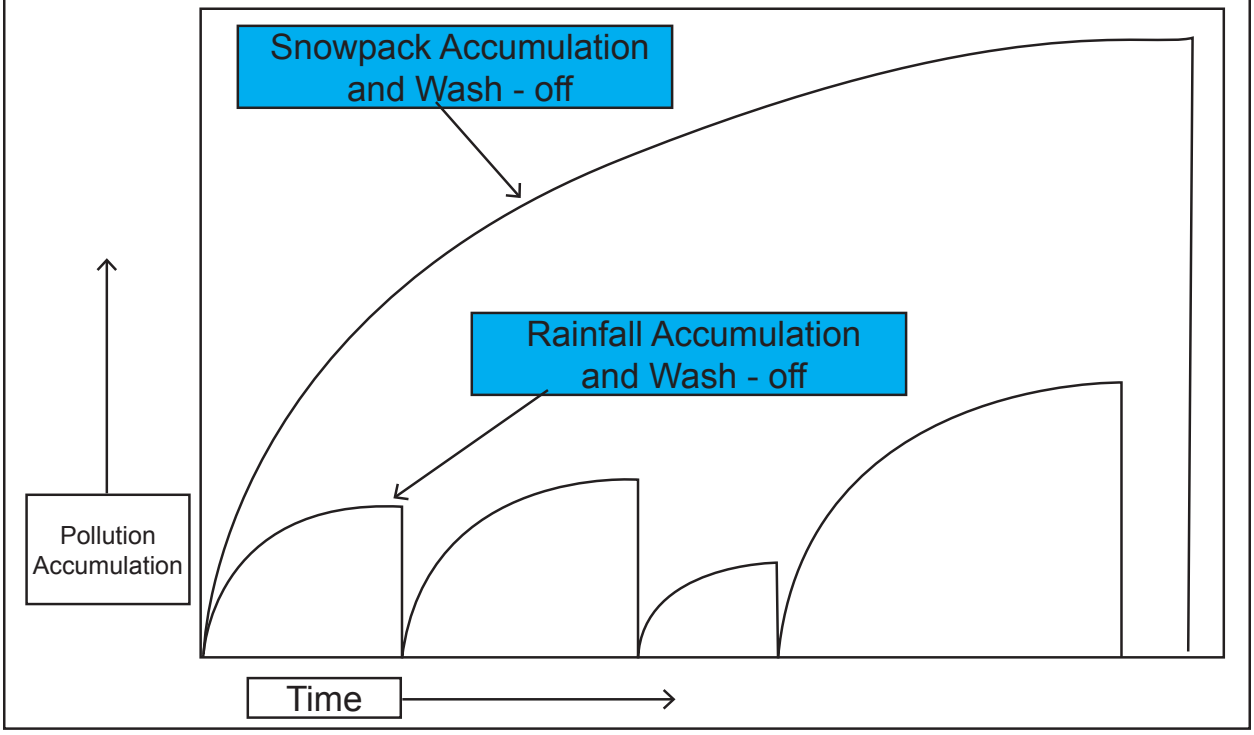
Figure 6.1c Aeas Well Removed from Roadways and High Traffic





Source: Minnesota Stormwater Manual 2005

Figure 6.1 Snowpack Accumulation and Wash-off as Compared to Rainfall



Source: Minnesota Stormwater Manual 2005

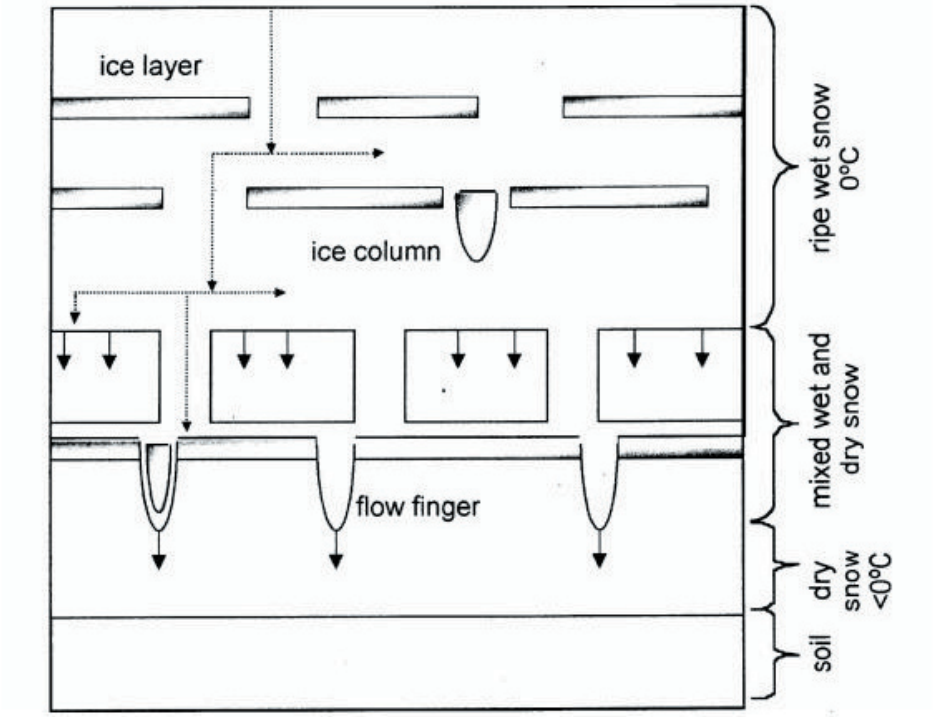
activity, aeration, settling, and pollutant degradation are altered by the cold temperatures, cold water and ice covered conditions that prevail for many months.

The variability of snow character and the repeated freeze-thaw cycles that occur throughout a long winter create a very heterogeneous snowpack. The complex melting pattern that occurs within a snowpack results in the release of pollutants at different times during the melt. The early part of the melt involves the very efficient elution of soluble constituents (ex. Cl, dissolved metals and nutrients, dissolved organics) at the crystal edges, yielding a highly soluble, acidic, and potentially toxic runoff volume. This process known as the first flush, results in a substantial release of the soluble component of a snowpack, often resulting in a “shock” effect as these pollutants reach a receiving water body. Later in the event, melt water from the snowpack is depleted in these soluble contaminants, but water flow can be at its highest providing enough energy to carry with it the finer-grained solids and associated contaminants (ex. hydrophobic PAHs) and leaving behind the larger particles. Alert sweeping can pick coarse material up from paved surfaces if there is an opportunity between the departure of snow and the first rains.

An end of the season rain-on-snow event often presents the worst-case scenario when rain falls onto a deep, possibly saturated snowpack. When this occurs, the movement of a well defined, rapidly moving wetted front through the snowpack results in the mobilization of soluble constituents and the energy associated with the rainfall is sufficient to mobilize the fine-grained or possibly larger solids and associated contaminants. This wave of melt also washes over urban surfaces and picks up material that has been deposited on these surfaces all winter. Meltwater can be extremely concentrated in many different toxic substances (metals, PAHs, organics, free cyanide, chloride). A major portion of annual pollutant loading can be associated with spring melt events.

Figure 6.3 shows how melt water can move downward in a snowpack through different flow-paths around “dry” snow and ice layers caused by repeated freeze-thaw cycles. As this water moves through, it picks up

Figure 6.3 Percolation of Water Through a Snowpack



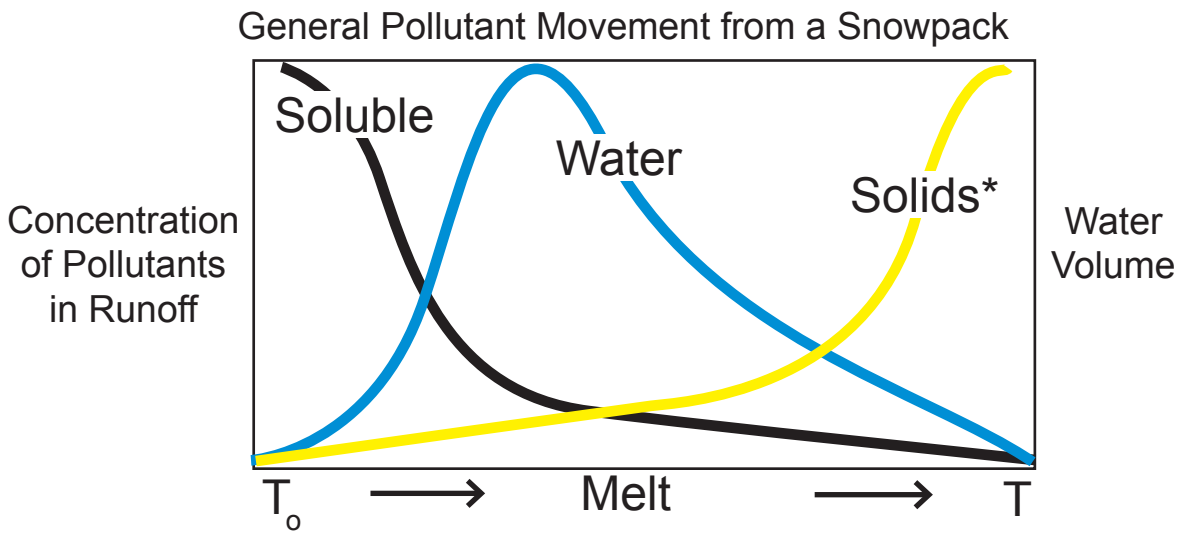
Source: UNESCO 2000, Chapter 2 of Semadeni-Davies and Bengtsson, as Adapted from Marsh and Woo, 1984

or mobilizes soluble ions that have pushed to the edge of ice crystals. Through this process, the snowpack cleanses itself of soluble contaminants that become available in the first phases of the melt, yielding a highly soluble, acidic and perhaps toxic (to animal and plant-life) runoff volume. Later in the event, melt water from the snowpack is depleted in these soluble contaminants, but water flow can be at its highest. Energy levels are only high enough to move fine- to medium-grained particulates when the snowpack allows their passage, leaving behind the coarser-grained material. The coarser material is available for wash-off during the higher energy spring rainfall events, and becomes a major source of contamination at that time. Alert sweeping can pick this coarse material up from paved surfaces if there is an opportunity between the departure of snow and the first rains.

The management implication of the preferential elution (or chemical dissolution) process is illustrated in Figure 6.4. The graphic shows that the early part of the melt involves the very efficient elution of soluble constituents (ex., Cl, dissolved metals and nutrients, dissolved organics) at the crystal edges, resulting in a substantial release of the soluble component of a snowpack, often resulting in a “shock” effect as these pollutants reach a receiving water body. Following the release of soluble is a period when much of the liquid volume of the snowpack releases (skewed toward the earlier part of the mid-melt event) and carries with it the remaining solubles along with the beginning portion of finer-grained solids and associated contaminants (ex. hydrophobic PAHs).

This mid-melt period generally has the largest portion of water runoff associated with the melt, and the mobilization of solids begins and continues as long as sufficient energy is available to move the finer particles, leaving behind the larger particles.

Figure 6.4 Residential Subdivision Illustrating Preservation of Natural Areas



Early	Middle	Late
Character		
High soluble content	Remaining solubles, beginning of fine- to medium-solids	High solids content
Low runoff volume, early infiltration	Large runoff volume	Large runoff volume (especially if rain-on-snow occurs), saturated soils
Initiated by chemical addition and/or solar radiation	Largely driven by solar radiation, aided by salt	Solar driven
Land Use Where Important		
Low density	High density	High density
Residential/neighborhood	Roads, parking lots	Roads, highways
Open space	Snow storage sites	Commercial
BMP Focus		
Infiltration	Pretreatment (settling)	Pretreatment (settling)
Dilution	Volume control	Filtration
Pollution prevention (salt, chemical application)	Detention/settling	Volume control
Retention		Pollution prevention (surface sweeping)
Wetlands/vegetation (infiltration, biological and soil uptake)		Detention/settling
Diffuse runoff paths		Wetlands/vegetation (filtration, settling)

Source: Minnesota Stormwater Manual 2005

Frozen Soils

Several studies have shown that frozen ground interferes with infiltration and reduces infiltration rates. These reduced rates are the result of a combination of things including frozen ground, formation of ice lenses, ice within soil pore spaces, snow cover, and depth of frost penetration. This interference however, only completely eliminates infiltration in the case of soils that are saturated upon freezing. Under most circumstances, infiltration through the soil profile still occurs. Temperature then becomes the primary factor in determining a soil's permeability under frozen conditions. In certain cases the freezing and thawing processes can actually increase the hydraulic conductivity of a soil through cracking (Benson et. al., 1995).

Spring melt is a complex process and occurs unevenly even at a site scale. Melt water tends to accumulate in depressions where it may be unable to drain for several days due to the underlying frozen soils. Thaw of the soils is patchy, usually occurring after the ground surface is exposed by melting snow, but it may occur more rapidly under ponds of melt water, allowing them to drain quickly through the thawed soils opening.

Wetland, Open Space and Biological Impacts

There are scant data available on the impact of meltwater on wetland systems and associated open space areas. This information is critical when the use of "natural systems" for runoff management is increasingly promoted. Among the impacts are species shifts to less desirable species, increased toxicity to various biota, and decreased diversity. Appendix E contains a list of recommended vegetative species for use in various surface water management approaches in Minnesota. A very good resource on the topic has been produced through MPCA, entitled *Plants for Stormwater Design - Species Selection for the Upper Midwest* (Shaw and Schmidt, 2003).

Groundwater Impact

The most damaging meltwater component affecting groundwater appears to be the two elements associated with the most commonly used road salt - Na and Cl. The damage begins at the soil interface where Na can displace Ca and Mg and disrupt the physical structure of the soil column. Chloride can lower pH and dissociate heavy metals into more soluble and mobile forms. Although both of these chemicals can continue to migrate downward, it is mostly the Cl that presents a major threat.

Key Challenges in Engineering and Design

List of Complicating Factors for Cold Climate Design

The physical and chemical processes under way in a snowpack present an extremely complicated and variable set of phenomena. The freeze-thaw cycle and the elution of chemicals that it drives have been understood for many years, but details on the migration and management of the many chemicals of concern from the snowpack are seldom pursued by runoff managers. In 1997, the Center for Watershed Protection produced a design manual intended to address many of these problems. One of the items reported in that manual was a survey of cold climate stormwater managers asking what the challenges were that they faced. Table 6.1 below is a reproduction of a table from the CWP report.

A special session was held at the 2003 Maine Cold Climate Conference during which practitioners were asked the same question. Also, a public input meeting during the development of this manual noted the basic problems in Table 6.1 were still of concern to managers. Frozen conditions complicate the movement and treatment of meltwater or rain-on-snow runoff. While no new practices exist to treat this runoff, some adaptation of our existing approach to design and snow management could be the key to addressing this situation in cold climates

Table 6.1 BMP Design Challenges in Cold Climates	
Climatic Condition	**BMP Design Challenge**
Cold Temperatures	▶ Pipe freezing ▶ Permanent pool ice covered ▶ Reduced biological activity ▶ Reduced oxygen levels during ice cover ▶ Reduced settling velocities
Deep Frost Line	▶ Frost heaving ▶ Reduced soil infiltration
Short Growing Season	▶ Short time period to establish vegetation ▶ Different plant species appropriate to cold climates than moderate climates
Significant Snowfall	▶ High runoff volumes during snowmelt and rain-on-snow ▶ High pollutant loads during spring melt ▶ Other impacts of road salt/deicers ▶ Snow management may affect BMP storage

Management Approaches

Meltwater Management

Special management of cold weather runoff is usually required because of the extended storage of precipitation and pollutants in catchment snowpack, the processes occurring in snowpack, and the changes in the catchment surface and transport network by snow and ice. The discharges that come from urban meltwater may cause physical, chemical, biological and combined effects in receiving waters and thereby limit their quality, ecosystems and beneficial uses.

For many years the old adage “one size fits all” was tried for the management of all runoff management. Once the effects of this approach were scrutinized, however, it became apparent that applying traditional rainfall runoff BMPs was not working for meltwater in spite of their success with rainfall. The problem is usually not the large volume resulting from a significant event, although serious flooding certainly can occur. Rather, it is that the BMPs can be prevented from working as intended because of ice, cold water, highly concentrated pollution and lack of biological activity. Complications encountered in cold climates can work against many of the commonly used warm weather BMPs, reinforcing the need for the development or adaptation (e.g. revised criteria and specifications) of existing treatment practices to better address melt runoff. Additionally, the reduced performance exhibited during cold weather is generally not considered when management approaches are designed because of the perceived uselessness in trying to overcome the items presented in Table 6.1. The problems cannot be entirely negated, but any improvement in the quantity and quality of runoff will be a step forward.

Typical results of the conditions listed above include flow by-passing and flooding, lack of reaeration in the water column, pond stratification, decreased settling and biological uptake, flushing of previously settled material, and reduced infiltration capacity.

Management Sequence

The manner in which meltwater runs off of different contributing surfaces was previously addressed. This behavior suggests that a sequence be followed to intercept and treat variable quantities and qualities of runoff as they emerge. It is required that the following approach be used in planning a strategy for optimizing treatment effectiveness (see sidebar). Specific BMP adaptations to account for these strategies will be discussed later in this section.

Pollution Prevention

Keeping contaminating materials away from paved surface and out of accumulated or dumped snow is the key to minimizing the pollution associated with meltwater runoff. The management approaches that should be developed to accomplish this include:

- Judicious use of de-icing and anti-skid chemicals, which then indirectly control secondary effects like heavy metal speciation and soil character changes from Cl
- Less additives like cyanide (CN) to salt
- Better chemical storage and mixing (covered storage and mix areas, mix only needed amount)
- Improved application technology with trucks, such as weather monitoring, direct application to roadway, and brine wetting
- Design of Cl dilution system to lower its direct impact

Snow Removal/Storage

The common Minnesota practice of pushing piles back from the paved surface as far as possible is encouraged. Research has shown that up to 90% of the pollution accumulated next to roadsides over the winter is deposited within about 25 feet of the road surface. Keeping the melt from this area off of the paved surface to the maximum extent possible is a positive water quality management strategy as it reduces exposure of the

The 5 Steps for Management

Step 1 - Pollution Prevention

Pollution Prevention is always the best way to manage the quality of runoff from urban and rural surfaces (see next section).

Step 2 – Snow Removal/Storage

The plowing, relocation and collection of snow presents some very real management issues. Recommended locations for snow storage are contributing areas to pretreatment BMPs (see next section).

Step 3 – Meltwater Storage and Pretreatment

The highly soluble and perhaps toxic "first flush" should be pretreated to the extent possible. This pretreatment will prevent the downstream infiltration practice from clogging with fine- and medium-grained solids being transported in meltwater as well as protect the groundwater resources from the potential impacts of pollutants typically associated with meltwater. Given the pretreatment requirements for infiltration practices in the NWA, there will be ample opportunity to treat meltwater although some cold climate adaptations may be necessary (see next section).

Step 4 – Infiltration

After the meltwater has been routed through a pretreatment practice, it should be suitable for infiltration. While the pretreatment practice may not remove all of the fines and pollutants typically associated with meltwater, the treatment available from infiltrating meltwater through soil (filtration, ion exchange, adsorption, and biological decomposition/transformation) will remove many of the most polluting contaminants typical of low-density urban areas (see next section).

Step 5* - Housekeeping

Much of the remaining solids are too heavy to be moved by melt so they remain near the roadside, in gutters, or in the location they were dumped as part of a snow pile, available for wash-off when spring rains come. After the snowpack has totally melted and before the first rainfall (if possible) preventive measures such as street and parking lot sweeping should be pursued. Note that Step 5 could occur after Step 1 for those facilities that practice cleaning activities during the winter.

Typical Snow Management Techniques

Figure 6.5a Snow Plowed Off the Road and Laft Piled on the Roadside



Figure 6.5b Snow Plowed Off Commecial Parking Lot and Piled in Corner



melt to particulates in the roadside area so adsorption can occur.

In most urban areas, a number of approaches are followed depending upon the level of urban density. In residential areas, snow is generally plowed to the side of the road and allowed to accumulate there all winter long. However, in commercial/ industrial zones, snow is often plowed to a corner of a parking lot, and in densely developed urban centers, snow is often removed to a totally different, often remote area, where it is dumped for an entire winter season (Figures 6.5 a and b in sidebar – see sidebar figure on page 16 Chapter 9 Volume 2 of Minn. Manual)

Local practices seem to vary considerably based on tradition, expectations and the cost of removal operations. Assuming snow is collected, the design of "snow dumps" must take into account the fact that snow eventually melts and needs somewhere to flow, either off of the land surface or into the ground.

There has been a shift in recent years by many public works departments to reduction in anti-skid sand and greater use of salt. This shift has been propelled by the high cost of removing sand from street surfaces and stormwater conveyance and treatment systems. If this trend continues, the adverse impact of salt on Minnesota's receiving waters is likely to increase. As difficult as sand is to deal with, it is generally inert and can be easily removed. Salt is a conservative substance that readily migrates into soil, groundwater, lakes and streams, causing problems at each step along the way. Alternatives to NaCl for road salting are not currently feasible because of cost (high relative to NaCl) and secondary environmental effects (like high BOD). Until such alternatives become available, a wise-use ethic should be the goal of every salt user. Adaptations in equipment, adequate driver training on application methods, and monitoring of driver salt use are other approaches to wiser salt use.

The following snow removal/storage guidelines should be adhered to in the NWA:

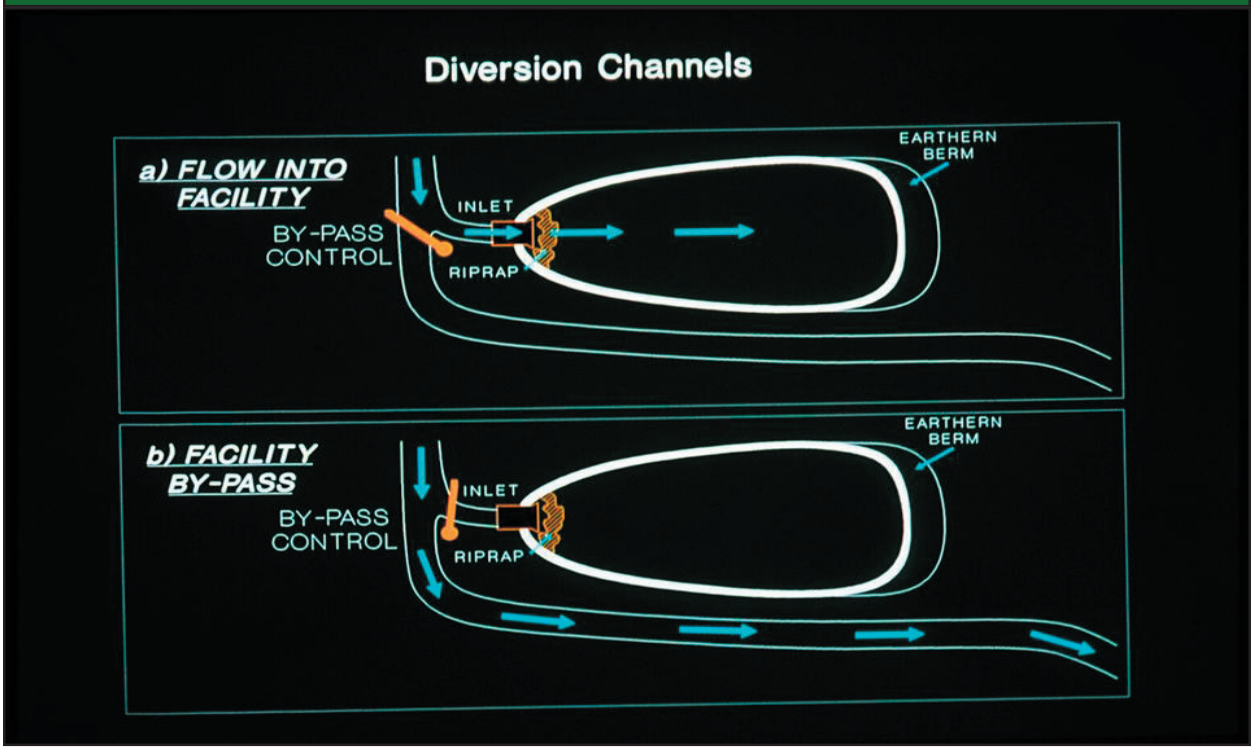
► Collect snow on a pervious pad and divert melt for treatment (e.g. pretreatment practice, detention, routing to a wastewater treatment facility).
► Develop a road de-icing plan that minimizes the use of road salt and identifies proper application techniques.

Meltwater Storage and Pretreatment

The highly soluble and perhaps toxic "first flush" should be pretreated to the extent possible provided the source area is not concentrated in Cl or other toxic pollutants. Given that the pretreatment requirement for the NWA is the removal of 85% TSS, it will be the Designers responsibility to evaluate whether or not additional treatment is necessary given the meltwater being routed to the facility during winter months. More information on the pretreatment requirements for the NWA can be found in Chapter 7.

If the Designer finds that it is infeasible to treat meltwater with high concentrations of Cl or other toxic pollutants, routing meltwater away from the pretreatment/infiltration system is an active meltwater management decision that can be made depending upon specific site conditions. For example, highly Cl-laden water can be routed away from an infiltration system that might operate during three seasons, but not the winter (see Figure 6.6).

Figure 6.6 Infiltration Design Adaptation Illustrating Re-Routing of Highly Cl-laden Meltwater



Source:

The following sections address some of the cold climate considerations associated with specific pretreatment practices.

Stormwater Ponds

Difficulties applying warm weather detention concepts to cold weather meltwater treatment occur because of the higher runoff volumes and increased pollutant loads, ice layers and frozen/sand-plugged conduits, anaerobic conditions, greatly enriched under-ice accumulation of pollutants, circulation problems and resuspension.

There are many processes that work to limit the effectiveness of ponding during meltwater events, including:

- Pond stratification;
- Anaerobic conditions;
- Release of pollutants from both bottom sediment and interstitial waters that were once thought to be permanently removed; and
- Displacement and flushing of highly polluted under-ice pond water with the first waves of meltwater that sink below the ice layer in ice-free areas near the inflow.

In spite of the fact that detention systems may not work well under typical designs in cold weather, they play a prominent role in the treatment of meltwater. Near paved areas, particulate content can become extremely high because of a winter's accumulation of anti-skid sand and urban debris. Routing this runoff to a detention facility prior to release to an infiltration practice or a receiving water is recommended. The large mass of particulates near these surfaces also plays an important role in adsorbing and settling soluble pollutants that otherwise might escape further treatment. For both of these reasons, an adapted ponding system is first among the list of recommended treatment methods for meltwater management. Specific adaptations are presented in the next section of this chapter.

It is important to recognize the potential pollution problems that Cl and toxic contaminant build-up in a pond can cause when released. A delicate balance needs to be pursued in deciding whether to adjust pond levels to pass Cl-laden water downstream or retain as much as possible for later release when flows are higher. Retaining polluted water all winter long only to discharge it all at once in the spring is not is the best interest of an infiltration facility, underlying groundwater resources or a downstream receiving water body, but this is what can happen in a pond not managed for seasonally changing conditions.



In no case should ponds be drained in the spring following a winter's long accumulation of under-ice contaminants. If lowering is done, it should be done in the late fall before freeze-up.

Wetland and Biological Based Systems

Wetlands and biological-based systems often act as modified detention facilities by virtue of their sheer numbers and the location they occupy in the drainage landscape. Most of the constraints listed above for ponds also apply to the proper operation of wetland treatment systems. In addition, however, is the sparse biological activity present during the cold weather season. Vegetative uptake, filtering and microbial activity are all effective mechanisms to reduce pollution related to biological activity during warm weather that are much reduced when the weather is cold. Although sedimentation might continue to play a role in meltwater treatment, provided an ice layer does not prevent it, decomposition, chemical adsorption and biological transformation will all likely be reduced.

Even though the pollutant removal effectiveness of biological systems is less during cold weather, these systems certainly have their place in an overall runoff management program. Low-lying wetlands and bioretention areas are the first place that soluble-laden first meltwater will migrate and soak into the ground. Standing vegetation, although not green and vibrant, still provides a measure of filtration as meltwater flows through. Soil microbes still live and consume nutrients even in the dead of winter. Accumulation of Cl is generally not a problem in shallow biological systems, as long as very highly concentrated levels are not routed directly to them, and even when this does occur, salt tolerant vegetation can survive. For more detailed information on salt tolerant vegetation see Appendix B of this Manual.

Filtration, Hydrodynamic Structures and Treatment Trains

Filtration through a granular inorganic (sand, perlite) or organic (compost, leaf pellet) medium can be a fairly effective way to treat many of the pollutants associated with meltwater. These systems can be particularly effective when placed as a sub-grade unit below the frost-line. Sub-grade construction also allows for surface land to be used for other things, such as parking or open space.

Many new proprietary management systems are on the market today with promises of year-round effectiveness. While many of these proprietary systems are promising, most are untested in cold climates. The most promising practices for meltwater are the treatment trains that incorporate settling, floatables skimming, and filtration through some kind of organic or synthetic media. Theoretically, these systems should be able to settle the solids associated with anti-skid grit added over the winter, then remove a fair portion of the soluble toxics also washing off in a melt. Unfortunately, conservative elements like Cl will move through most systems unchanged.



Many new proprietary management systems are on the market today with promises of year-round effectiveness. Many of these systems are promising, yet most are untested in cold climates.

Infiltration

Although infiltration has not been a commonly used meltwater BMP in Minnesota, studies from many similar climates show that it is a feasible practice when used with precautions. As Chapter 5 indicated, specific BMPs that involve infiltration include practices such as trenches and basins, pervious surfaces, vegetated swales and bioretention. Additional criteria for the design of infiltration practices is provided in Chapter 8 of this Manual.



Snow deposits should not be located directly over an infiltration facility because of the possibility of clogging from debris in the snow.

Housekeeping

Much of the remaining solids are too heavy to be moved by melt so they remain near the roadside, in gutters, or in the location they were dumped as part of a snow pile, available for wash-off when spring rains come. After the snowpack has totally melted and before the first rainfall (if possible) preventive measures such as street and parking lot sweeping should be pursued. The following housekeeping guidelines should be adhered to in the NWA:

- Rapid sweeping as soon as snow is gone from paved surfaces
- Litter control
- Erosion control

Design Adaptations for Cold Climates

BMP Sizing for Snowmelt

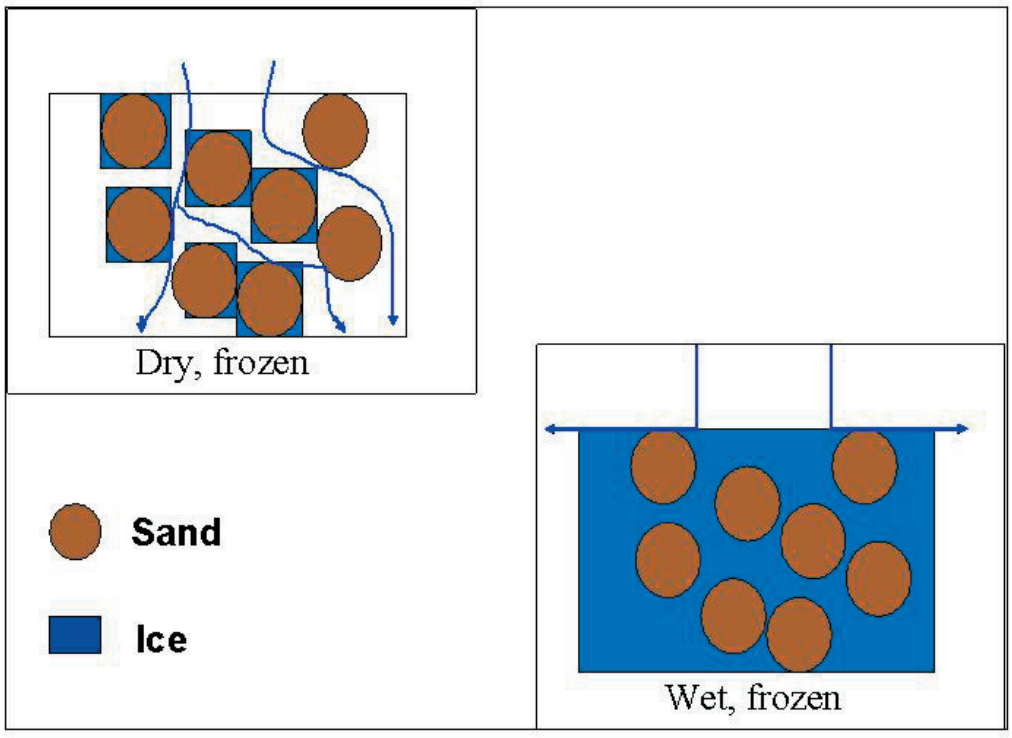
Climatology data supports a common rule of thumb that most of the snowpack disappears in the spring over a period of about ten days. The question can be raised as to why this volume should be important if BMP facilities are generally designed for treating a runoff event lasting only 24-hours. That is, aren't we merely dealing with on average 1/10th of a snowmelt runoff volume going into a facility designed to treat a much larger volume? Clearly, if the systems are built to store a large volume of rainfall runoff, there will be no problem. The difficulty arises when complicating factors in cold weather prevent the full storage volume for a pond, or infiltration capacity of an infiltration device, or conveyance for a diversion to be available during the period of time when they are designed to operate. Suddenly snowmelt could receive less than adequate treatment or by-pass any treatment whatsoever. The following cold climate adaptations need to be addressed in designing stormwater BMPs in the NWA.

Infiltration Practices

Depending upon the need, various options for the use of infiltration in cold climates are available. Some of the installations are built below the frost-line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. Surface systems, however, may need some special consideration.

The problem with infiltration in cold weather is the ice that forms both over the top of the facility and within the soil interstices (Figure 6.7).

Figure 6.7 Applicability of BMPs for Cold Climate Use



Source: Minnesota Stormwater Manual, 2005

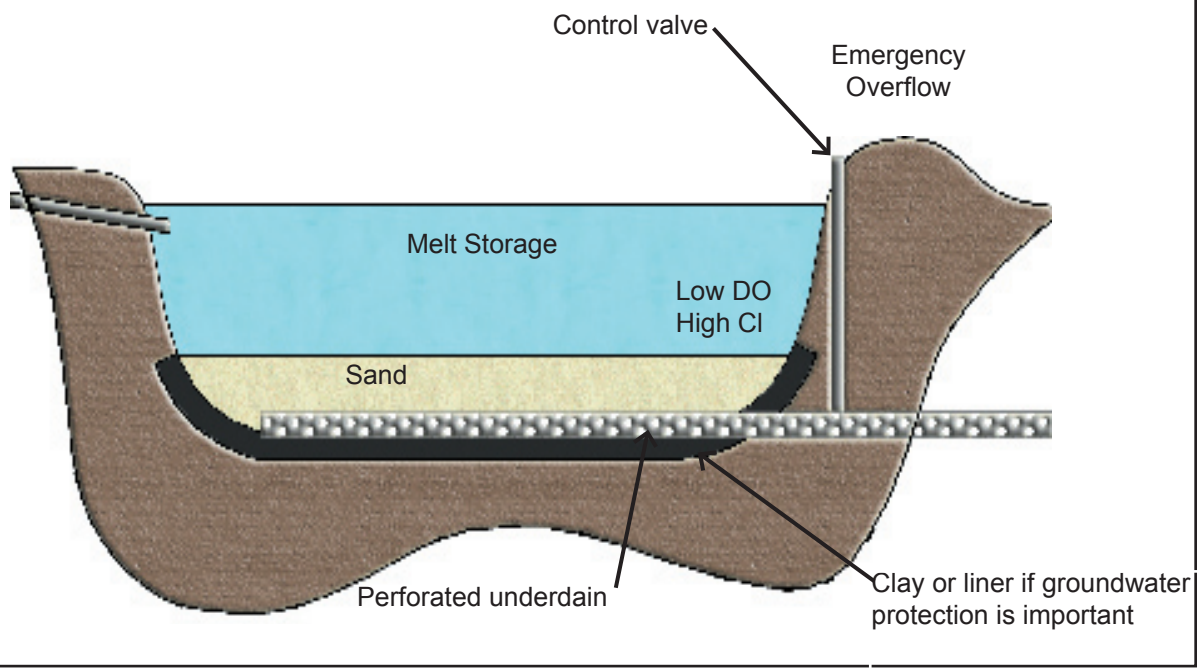
To avoid these problems to the extent possible, the facility must be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods including limiting inflow, under-drainage and surface disking. Even if the infiltration properties of an infiltration basin are marginal for melt, the storage available in the facility will provide some storage if it is dry entering the melt season. Again, the designer is required to evaluate the need for additional pretreatment given the source and quality of meltwater being routed to the infiltration practice during winter months and in the spring.



Infiltration practices must be actively managed to keep it dry before it freezes in the late fall. Given the source and quality of meltwater, additional pretreatment may be necessary.

Figure 6.8 is a general graphic portrayal of an infiltration basin adapted for handling spring meltwater runoff. The adaptation in this graphic is a sub-drain installed to dewater the basin of any water heading into the freeze-up. This drain can be closed just prior to meltwater inflow and during the non-winter seasons to allow infiltration to continue downward. Also note that a clay liner can be added if the need to protect local groundwater from infiltrating meltwater is important. If this adaptation is made, the basin is no longer an infiltration system, but instead becomes a filtration system or dry pond.

Figure 6.8 Seasonal Infiltration Basin (or Filtration Basin if Liner Installed)



Source: Minnesota Stormwater Manual, 2005

Proprietary, sub-grade infiltration systems provide an alternative to standard surface based systems. These systems, in essence, provide an insulated location for pre-treated meltwater to be stored and slowly infiltrated, or simply filtered and drained away if groundwater sensitivity is an issue. The insulating value of

these systems adds to their appeal as low land consumption alternatives to ponds and surface infiltration basins.

Filtration Practices

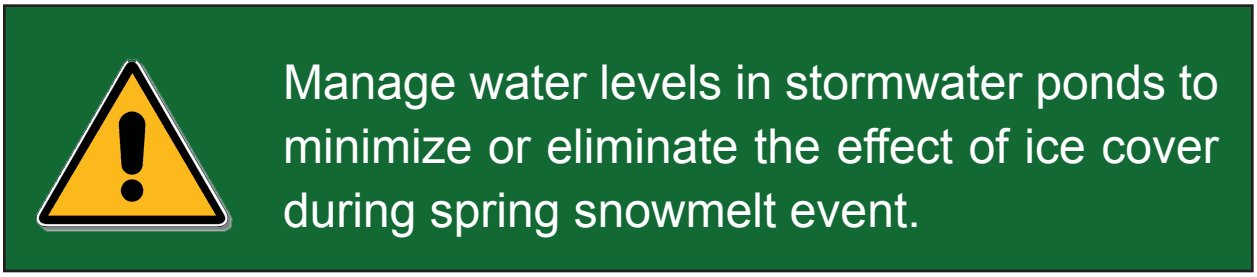
In cold climates, stormwater filtering systems need to be modified to protect the systems from freezing and frost heaving. Physical design and operational considerations to keep in mind for filtration systems are included in Chapter 8.

Stormwater Ponds

The difficulties of operating an effective storage and treatment pond in a cold climate were discussed previously. Problems exist with the thick ice cover (lack of reaeration, "impervious" cover for settling purposes, reduced storage volume) and under the ice (anaerobic conditions, resuspension of settled material, concentration of Cl and toxic material, dissolution and density stratification).

To overcome these difficulties, some seasonal adjustments can be made to account for winter conditions. The obvious need in this situation is to eliminate the effect of the ice layer. This layer can be up to several feet thick during a hard winter and can greatly reduce the availability of the designed storage volume. The result is usually a small amount of the initial melt diving under the ice in a somewhat pressurized manner forcing out water that might have sat stagnant all winter long. When the available capacity provided by limited uplift of the ice cover is filled, meltwater begins to flow over the top of the ice, which usually means outflow at the other end after very limited exposure to settling due to the "impervious" ice cover.

Minimizing the effect of the ice cover can be done passively through the design of surplus storage or actively through the management of water levels before ice has a chance to form and after meltwater inflow begins. While the following adaptation requires more active management, it is required for the NWA as it will result in improved performance and fewer downstream water quality problems. The significant change made in this adaptation (Figure 6.9) is the addition of a controlled outlet mechanism for the permanent storage pool. Lowering this pool to a lower level will minimize the effect of an ice layer and maximize the storage available once the lower control is closed and the large spring melt occurs. The poor under-ice water quality concerns will be minimized. The "reclaimed" storage volume will equal most of the permanent pool and all of the water quality volume. The storage of all phases of the melt sequence means that solubles will be held, volume will be stored, and particulates will have a chance to both adsorb soluble pollutants and settle.

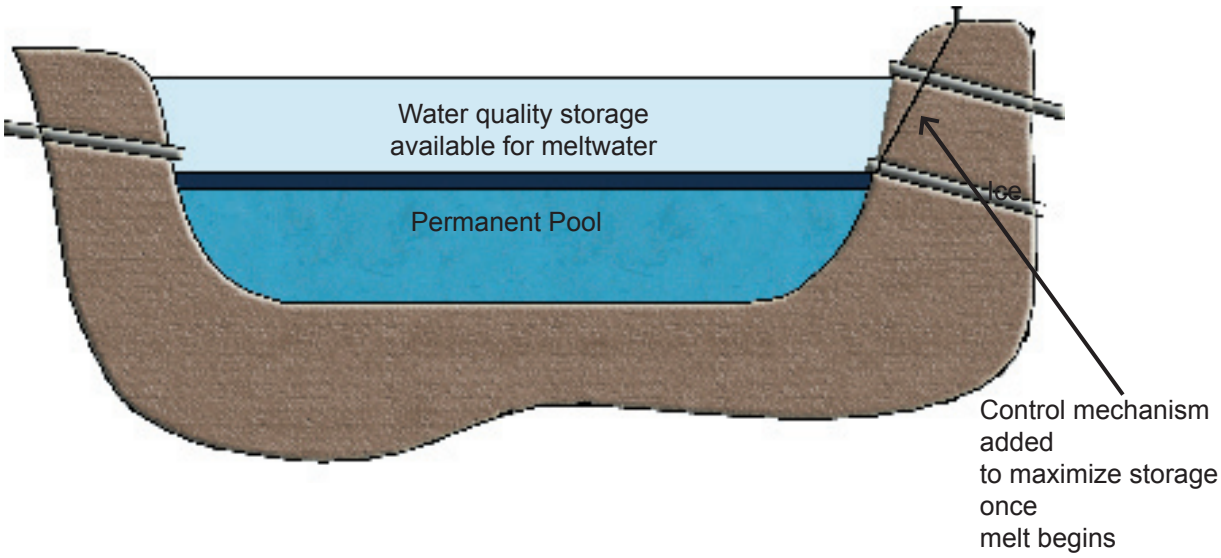


One caution for this system is that the permanent pool could completely freeze or possibly disappear entirely if the drawdown is complete. Since maintaining a healthy biological system is part of a successful detention system, it is recommended that the permanent pool not be drawn too far down such that total freeze-up or elimination occurs.

Details on various outlet configurations are also provided in Chapter 8. Some basic outlet concepts, however, should be mentioned. Perhaps as important as the layer of ice over the permanent pool is the blockage or hindrance of outflow from a pond because of a frozen outlet. There is a need to get water from under an ice layer to exit in a manner that does not cause splashing or gradual freezing of layer after layer

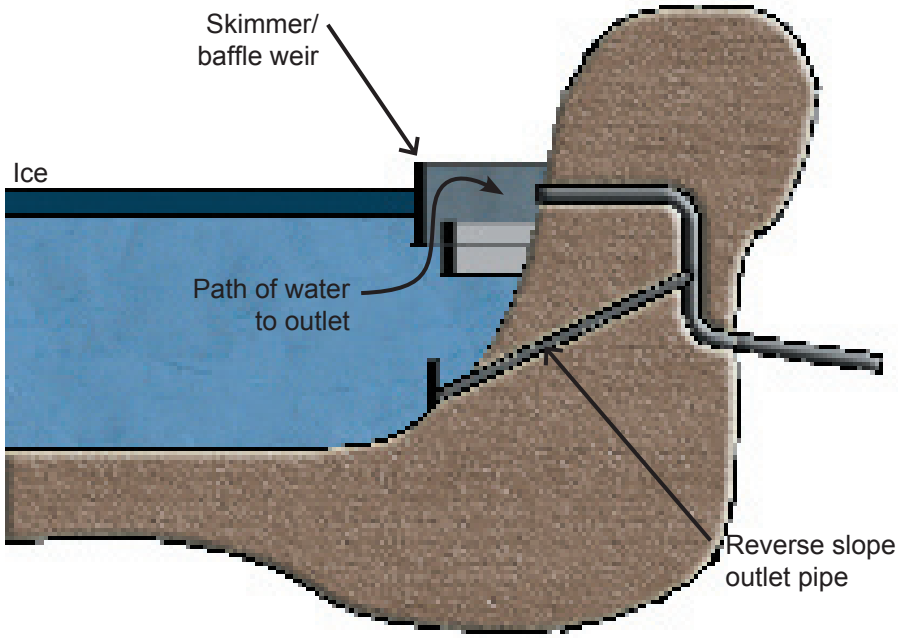
of outflow. Drawing water from below the ice via a reverse sloped outlet pipe and installation of a skimmer device (baffle weir) that draws water from below the ice are two options shown in Figure 6.10.

Figure 6.9 Simple Meltwater Storage



Source: Minnesota Stormwater Manual, 2005

Figure 6.10 Drawing Outflor Water from Below the Ice



Source: Minnesota Stormwater Manual, 2005

III. Potential Stormwater Hotspots (PSHs)

Background and Designation of PSHs

PSHs are defined as commercial, industrial, institutional, municipal, or transportation-related operations that produce higher levels of stormwater pollutants, and/or present a higher potential risk for spills, leaks or illicit discharges (Schueler *et al.*, 2004). It is important to note that designation as a PSH does not imply that a site is a hotspot, but rather that the land use and associated on-site activities have the potential to generate higher pollutant runoff loads compared to other land uses. Designation as a PSH serves as a useful reminder to designers and reviewers that more careful consideration of the site is warranted. One of the design considerations should be an evaluation of the need for additional pretreatment prior to discharge to an infiltration practice. Ultimately, a PSH site designation may dictate that certain practices and/ or design criteria are promoted or discouraged. Table 6.2 provides a listing of potential PSHs associated by major land use category. A description of the major land use category is provided below.

Table 6.2 Examples of Potential Stormwater Hotspots (PSHs)

Land Use Category	Land Use	
Commercial	▶ Animal care services ▶ Building material ▶ Commercial car washes ▶ Convenience stores ▶ Laundries and dry cleaners ▶ Lawn care companies ▶ Gas stations	▶ Nurseries and garden centers ▶ Petroleum wholesalers ▶ Fast food restaurants ▶ Shopping centers ▶ Vehicle maintenance and repair ▶ Wholesale food and beverage
Industrial	▶ Auto recyclers ▶ Boat building and repair facilities	▶ Recycling centers and scrap yards ▶ Warehouses
Institutional	▶ Cemeteries ▶ Churches ▶ Colleges ▶ Corporate office parks	▶ Hospitals ▶ Private schools ▶ Private golf courses
Municipal	▶ Composting facilities ▶ Fleet storage and school bus depots ▶ Landfills/solid waste facilities ▶ Local streets and storm drains ▶ Pesticide use in rights-of-way ▶ Public golf courses	▶ Public schools ▶ Public works yards ▶ Maintenance depots ▶ Solid waste facilities ▶ Wastewater treatment plants
Transport Related	▶ Airports ▶ Bus depots ▶ Rental car lots ▶ Railroad stations and associated maintenance facilities	▶ Ports ▶ Highway maintenance facilities ▶ Trucking companies and distribution centers

*Please note that this list is not all-inclusive, nor does mention here indicate that all such occurrences will be PSHs; rather, these are examples of typical land uses that could be PSHs.

Commercial PSHs

Commercial PSHs consist of a small group of businesses associated with a specific activity or operation that generates higher pollutant loads in a subwatershed. Each kind of commercial hotspot generates its own blend of stormwater pollutants, which can include nutrients, hydrocarbons, metals, trash and pesticides. Commercial PSHs typically have a great deal of vehicle traffic, generate waste or wash water, handle fuel or repair vehicles, or store products outside. While commercial PSHs are quite diverse, they are often clustered together. Most commercial PSHs are unregulated, although a few are regulated under the NPDES industrial stormwater permit program, by local ordinance or by federal/state law if they handle even small quantities of hazardous material.

Industrial PSHs

Industrial PSHs are a major focus for pollution prevention if they use, generate, handle or store pollutants that can potentially be washed away in stormwater runoff, spilled, or inadvertently discharged to the storm drain system. Each type of industrial PSH generates its own blend of stormwater pollutants, but as a group, they generally produce higher levels of metals, hydrocarbons and sediment. Many industrial operations are regulated under the NPDES industrial stormwater permit program, although individual owners or operators may be unaware of their permit status.

Institutional PSHs

Institutional PSHs include larger, privately-owned facilities that have extensive parking, landscaping, or turf cover. In addition, institutions may contain fleet vehicles and large maintenance operations. By and large, institutional PSHs are not regulated. The most common pollutants generated by institutional PSHs are nutrients and pesticides applied to maintain grounds and landscaping.

Municipal PSHs

Municipal PSHs include many local government operations that handle solid waste, wastewater, road and vehicle maintenance, bulk storage areas for road salt and sand, and yard waste. Many of these municipal operations are regulated PSHs in MS4 communities. Municipal PSHs must prepare the same pollution prevention plans and implement source control practices as any other regulated PSHs. Municipal PSHs can generate the full range of stormwater pollutants, including nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash.

Transport-Related PSHs

Many, but not all, transportation related uses are regulated PSHs. They tend to generate higher loads of hydrocarbons, metals, and sediment in stormwater runoff, can be associated with large areas of impervious cover, and have extensive storm drain systems. Fluid leakage from these sites can be a major source of contamination, as can the addition of sand and salt during the cold weather season. Road surfaces are not automatically considered as PSHs unless they have been shown locally to be such sources.

Pollutant Generating Operations/Activities

Perhaps of more significant consideration, is an understanding of the types of pollutant generating activities that commonly occur in association with various PSH operations.

Vehicle Operations

Nearly all PSHs devote some portion of the site to vehicle operations such as maintenance, repair, recycling, fueling, washing or long-term parking. Vehicle operations can be a significant source of trace metals, oil, grease, and hydrocarbons, and are the first operations inspected during a hotspot source investigation. Vehicle maintenance and repair operations often produce waste oil, fluids and other hazardous products,

particularly if work areas are connected to the storm drain system. The re-routing of runoff away from a potential fuel wash-off location could eliminate this from the hotspot list.

Outdoor Materials

Most PSH sites handle some kind of material that can create stormwater problems if not properly handled or stored. The first step is to inventory the type and hazard level of materials at the site. Next, it is important to examine loading and unloading areas to see if materials are exposed to rainfall and/or are connected to the storm drain system. Third, any materials stored outdoors that could potentially be exposed to rainfall or runoff should be investigated. Public and private road salt and sand storage areas are of particular concern for this category.

Waste Management

Every business generates waste as part of its daily operations, most of which is temporarily stored at the site pending disposal. The third common hotspot operation involves the way waste products are stored and disposed of at the site in relation to the storm drain system. In some sites, simple practices such as dumpster management can reduce pollutants, whereas other sites may require more sophisticated spill prevention and response plans.

Physical Plant Practices

The fourth hotspot operation relates to practices used to clean, maintain or repair the physical plant, which includes the building, outdoor work areas and parking lots. Routine cleaning and maintenance practices can cause runoff of sediment, nutrients, paints, and solvents from the site. Sanding, painting, power-washing, resealing or resurfacing roofs or parking lots always deserves particular scrutiny, especially when performed near storm drains.

Turf and Landscaping

The fifth common hotspot operation involves practices used to maintain turf or landscaping at the site. Many commercial, institutional and municipal sites hire contractors to maintain turf and landscaping, apply fertilizers or pesticides, and provide irrigation. Current landscaping practices should be thoroughly evaluated at each site to determine whether they are generating runoff of nutrients, pesticides, organic carbon, or are producing non-target irrigation flows.

Unique Hotspot Operations

Some operations simply resist neat classification, and this last category includes unique sites known to generate specific pollutants. Examples include swimming pools, construction operations, golf courses, fairgrounds/racetracks, marinas, hobby farms, and restaurants. Water quality problems from very soluble Na, Cl and cyanide have been documented as resulting from stored salt piles. It is recommended that all public and private entities storing salt to follow the Salt Institute's (http://www.saltinstitute.org/) recommended BMPs, which include such things as covering, impervious pads and drainage routing.

Stormwater Management Design at PSHs

Understanding the types of future operations expected to occur on a site helps designers develop a more thoughtful stormwater management and pollution prevention plan for a given site. This approach provides more flexibility in terms of what stormwater treatment approaches are appropriate for different portions of a site. Runoff management at PSHs should also be linked to the pollutant(s) of greatest concern in the subwatershed. Similarly, understanding the pollutants potentially generated by a site operation provides designers with important information on proper selection, siting, design, and maintenance of the nonstructural (e.g., source control or pollution prevention) and structural practices that will be most effective at the PSH site.

The most cost effective approach to managing stormwater at potential hotspot sites is to employ a variety of non-structural pollution prevention, and source control measures. To do this effectively, it is necessary to have a thorough understanding of a site and the respective areas of the site where specific operations will occur. Hogland, *et al*. (2003) suggest most of the following principles for design:

- Develop detailed mapping of the different areas of the site along with associated planned activities and the preliminary drainage design.
- Separate hotspot activity areas from non-hotspot activity areas, if possible.
- Prevent or confine drips and spills.
- Enclose or cover pollutant generating activity areas and regularly provide cleanup of these areas.
- Provide spill prevention and clean-up equipment at strategic locations on site.
- Provide pre-treatment and spill containment measures such as catch basins and inserts, oil-water separators, etc.
- Strategically locate slopes and separation berms to prevent co-mingling of dirty and clean runoff.
- Retain and reuse stormwater for irrigation, wash down water, or other onsite uses.
- Maintain equipment to minimize leaks.
- Train and educate employees, management and customers.

Meeting the design intent of the non-structural practices above typically involves simple and low-cost measures to address routine operations at a site. For example, the non-structural design components for a vehicle maintenance operation might involve the use of drip pans under vehicles, tarps covering disabled vehicles, dry cleanup methods for spills, proper disposal of used fluids, and covering and secondary containment for any outdoor storage areas. Each of these practices also requires employee training and strong management commitment. In most cases, these practices save time and money, reduce liability and do not greatly interfere with normal operations.

After considering the non-structural elements to incorporate into a site based on its layout and proposed operations, designers need to assess what structural practices will be most appropriate given site constraints while providing the greatest pollutant loading reductions for targeted pollutants. Table 6.3 presents representative pollutant removal data for common PSH pollutants of concern as a function of practice group.

In the NWA it is often the protection of infiltration practices and ground water protection that will drive the criteria and associated practices that are acceptable for use. However, by virtue of being a PSH there are a set of general guidelines to always consider when designing structural stormwater management systems. The following guidelines should be carefully considered and incorporated as applicable by designers when specifying and siting BMPs at sites with PSHs.

- Convey and treat the non-hotspot runoff separately from the hotspot runoff. Pretreatment standards for hot-spot areas will be determined on a case-by-case basis based on contaminant(s) of concern. This evaluation will require up-front coordination with City staff.
- Infiltrate the non-hotspot runoff using the pretreatment standards identified in Chapter 7.
- The infiltration of runoff from PSHs may require oversizing sediment trapping features such as forebays and sedimentation chambers; incorporating appropriate proprietary and nonproprietary practices for spill control purposes and treatment redundancy; oversizing pre-treatment features for infiltration facilities such as swales, filter strips, and level spreaders.
- Consider closed systems with liners, under-drains, or comparable safeguards against infiltration for practices that manage hot-spot runoff.
- Establish rigorous maintenance and inspection schedules for practices receiving hot-spot runoff.

Infiltration practices are the practice group that requires the most scrutiny prior to implementation at a PSH. A conservative approach would avoid the use of infiltration practices at a PSH; however, with appropriate site and conveyance design it is possible for the designer to incorporate infiltration into many sites to treat areas sufficiently separated from pollutant generating activities. Most other practice groups should be acceptable for use in treating PSH runoff, so long as appropriate design modifications are incorporated. Most design

modifications are simple and in the form of enhanced pre-treatment, over-design, or design redundancies. Others are added features that limit the likelihood of ground water recharge. For example, practice groups such as bioretention, ponds and wetlands that receive runoff from pollutant generating activities should be designed with the necessary features to minimize the chance of ground water contamination. This includes using impermeable liners. The use of ponds and wetlands without liners should also be avoided where water tables are shallow and the practice would likely intercept the water table.

Table 6.3 Percent Removal of Key Pollutants by Practice Group

Practice	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydrocarbons [%]
Detention Ponds	25	60	70[2]	80[2]
Wet Ponds	30	60	70	80[2]
Stormwater Wetlands	30	40	75[2]	85[2]
Filtering Practices and Bioretention	35	65	45[2]	80[2]
Infiltration Practices[3]	50	80[2]	N/A	N/A
Vegetated Swales and Grass Channels[4]	80[2]	60	N/A	60[2]

1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. In the NWA, infiltration practices are not used for the pretreatment of stormwater runoff. Rather, there is a pretreatment standard of 85% TSS removal prior to discharge to an infiltration practice.
4. Higher removal rates for dry swales.

N/A: Data not available
Removals represent median values from Winer (2000)

Guidance on Infiltration of Runoff from PSHs

Preventing or minimizing the likelihood of contaminated runoff from leaving a PSH site is the core objective of stormwater management at these sites. Introduction of contaminated runoff to the ground water is probably the greatest concern in developing effective stormwater management plans at PSHs. There is a need for extreme caution when dealing with the introduction of stormwater runoff into the ground via infiltration systems or even low impact development-type techniques that encourage infiltration naturally. This is for three primary reasons: 1) ground water contamination is hard to detect immediately and therefore can persist over long periods of time prior to any mitigation; 2) there is an immediate public health threat associated with ground water contamination in areas where ground water is the primary drinking water source as it is in the NWA; and 3) mitigation, when needed, is often difficult and is usually very expensive.

Infiltration at PSHs relies on overall site design and facility operations management. Table 6.4 provides potential infiltration guidelines associated with each of the seven operational areas.

Good design and committed, well-trained facility staff should make infiltration possible for certain areas of the site. Where uncertainty is present, designers should avoid infiltration practices. The Minnesota Department of Health recommends that infiltration should not be used within the one-year wellhead protection area and limited in vulnerable wells for the 10-year wellhead protection area. Contact the MDH for specific information on exact locations.

Table 6.4 Infiltration Guidelines for Potential Stormwater Hotspots

Operational Area	Potential Infiltration Guidelines
Turf Practices	Infiltration okay so long as there is no co-mingling from higher pollutant loading areas and pretreatment standards are met. Hot-spot runoff may require additional treatment. Chemical management needed to limit the amount of fertilizer and pesticides added to the turf.
Downspouts	For commercial sites no polluting exhaust from a vent or stack deposits on the rooftop.
Parking Lots	Infiltration okay with following provisions: ► No direct discharge of hot-spot runoff from higher pollutant loading areas. ► Limited salt application or use of alternative deicers ► Pretreatment standards shall be met. ► Only daily "commuter" parking areas and no long-term car/truck storage sites
Waste and Material Storage*	Pretreatment measures must include spill prevention and containment measures such as catch basin inserts and oil and grit separators. Pretreatment may require redundancy such as filtering prior to infiltration. Infiltration should be prohibited in areas of exposed salt and mixed sand/salt storage and processing.
Loading Docks*	Pretreatment measures must include spill prevention and containment measures such as catch basin inserts and oil and grit separators. Also possible if redundant treatment is provided such as filtering prior to infiltration.
Vehicle Fueling*	Pretreatment measures must include spill prevention and containment measures such as catch basin inserts and oil and grit separators. Pretreatment may require redundancy such as filtering prior to infiltration.
Highways*	Infiltration possible where enhanced pre-treatment is provided as described under parking lots. Where highways are within source water protection areas and other sensitive watersheds additional measures should be in place such as spill prevention and containment measures (e.g. non-clogging catch basin inserts and oil and grit separators.
* Indicates operational area with likelihood of having higher pollutant loadings	

IV. Mosquito Control

Because stormwater management usually deals with the transmission, storage and treatment of water, there is much concern about the proliferation of mosquito breeding habitat associated with BMPs. This is a well-founded concern because mosquitoes will colonize any source of standing water provided there is a source of organic material to provide sustenance to larvae (Messer, 2003). Although this basic fact often means that BMPs will result in more mosquitoes, there are many design and management measures that can be followed to minimize this increase.

The primary threat to Minnesotans from mosquitoes, besides the nuisance, is the transmission of serious disease. West Nile Virus (WNV) and various forms of encephalitis are the major concerns. There are about 50 varieties of mosquito in the state, but only a few are efficient transmitters of WNV.

Minnesota is fortunate to have a major mosquito research and management agency in the Metropolitan Mosquito Control District (MMCD) which has been able to characterize the occurrence of mosquitoes and the problems they cause in the state. All mosquitoes need water for the larval and pupal stages of development. The larval stage lasts anywhere from 5-7 days, so holding water for less than five days will prohibit the progression of life past the larval stage. Standing water for over two weeks can easily breed mosquitoes if not treated.

The presence and behavior of water is the most important element to the continuing life cycle of the mosquito. Controlling standing and stagnant water, and adapting design and habitat conditions are the ways stormwater managers can avoid a proliferation of mosquito breeding in association with stormwater BMPs.

Stormwater Managers can take many actions to reduce the likelihood of problems with mosquitoes, including:

- Protect the water quality of all BMP facilities to avoid high levels of nutrient and algae (food for mosquitoes), low dissolved oxygen (inhibits development of predators like fish, frogs, dragonflies and damselflies), and stagnant water; be aware, however, that some mosquitoes thrive in clean water, where predation could be the most effective control
- Properly design and maintain all stormwater BMPs
- Work with vector control agencies on integrated pest management approach to larval control
- Maintain and clean-out sediment traps/basins and all drainage structures, inlets, outlets and orifices (use only openings >3” to prevent clogging) to keep positive water drainage
- Design facilities to minimize vegetation overgrowth, floating organic debris, algae, trash, sediment dead grass/clippings, and cattails
- Avoid the use of rip-rap that can catch and hold organic debris in a wet area
- Avoid the use of mulch that will wash into any BMP (use geotechnical material or secured mats instead)
- Keep dense emergent vegetation limited to narrow (<1m) bands around areas with standing water and prevent the development of cattail stands
- Avoid vegetation cutting operations that leave debris, blow into standing water, or leave ruts for water accumulation
- Do not allow water to collect in “temporary” facilities for longer than five days, preferably less than three
- Drain infiltration/filtration BMPs within 72 hours or 48 hours if it is being used to meet MPCA’s requirements
- Design healthy natural systems that encourage mosquito predators to thrive and have access to mosquito larvae; this includes open water (over four-feet deep) as part of wetland design (preferably oriented perpendicular to flow-through), minimization of stagnant, non-flowing water, creation of diverse vegetation only along periphery of ponds

- Eliminate standing stagnant water as part of any BMP appurtenance, including forebays, sediment traps, sump areas and pumps
- Use BSD/LID development techniques to reduce the amount of stormwater that needs to be conveyed and managed
- Minimize shallow depths (less than one-foot) as part of ponds and wetlands; if this cannot be done, make sure flow continually flows over the shallow area
- Keep permanent pool embankments steep to prevent emergent vegetation, especially cattails, from growing; carefully plan plant species for aquatic/safety benches to avoid cattail intrusion
- Minimize installation of BMPs that will collect stormwater for only brief periods then stagnate until the next event; this could include a water budget analysis to make sure some baseflow will occur through the BMP
- Avoid allowing standing water to collect in inlets and outlets and in conveyance pipes; avoid corrugated pipe without constant flow and sumps in catch basins
- Require written inspection and maintenance plan that addresses stagnant water, water quality, and vegetation and debris management
- Design de-watering capability into every BMP for routine dry-down and maintenance
- Place inlet and outlet pipes under water if no other control available (prevents fly-in)
- Always design access for vector control staff to reach entire BMP, not just the inlet or outlet

Compatibility with Common BMP Design

A cursory consideration of the list of commonly used Minnesota BMPs relative to the above list would seem to indicate that some BMPs might be more desirable than other when mosquitoes are concerned. Careful consideration of practices can avoid the mosquito impact, as follows:

- Avoiding excessive vegetative growth does not mean minimizing vegetation, rather it means keeping a healthy mix that thrives and does not overwhelm the BMP or an (upland) area adjacent to a BMP. The same applies for emergent vegetation that is planted as part of an overall planting scheme.
- Shallow vegetated benches are part of the recommended safety design for ponds. Although a recommendation above suggests that “shallow” water less than one-foot be avoided in standing water situations, it might be necessary, depending upon safety needs, to construct such a bench. In addition, a recommendation above suggests that dense periphery vegetation be limited to about 1m in width, whereas Chapter 8 recommends bench width at 10’. Designers are advised to use their judgment on the mix of recommendations for edge-of-pond depth, depending upon priorities for safety relative to mosquito control. Care should be taken in plant selection, particularly if bench depths less than one-foot are anticipated.
- Rip-rap or similar structural armor for bank stabilization are options that are sometimes needed in erosive situations. The tendency for these materials to capture vegetative debris and to create small pools of water make them ideal mosquito breeding sites. If mosquito breeding is a concern at these installations, smoothing with a grout material or size grading can be used to minimize edges and pools that promote mosquito habitat, or alternative materials can be used.
- Extended detention pools should recede within three days to minimize possible mosquito breeding. Floodwater mosquito egg-laying on the moist side slopes above the permanent pool is almost impossible to control in this situation because the eggs remain viable for up to five years and will wash into the pool whenever water levels rise. Standing water varieties can be minimized with a good vegetative management plan that allows these areas to fully dry out between events. If conditions cannot be improved to minimize breeding habitat, biologic larvicides should be used.
- Forebays, sediment traps and treatment sumps could all be part of a well designed treatment train. The recommendation above to keep these from becoming stagnant is consistent with good design principles and should not preclude their use. The essential elements in keeping them “fresh” are to either drain them fully after use or keep baseflow moving through them. MMCD began a monitoring program in underground structures in 2005 and has found evidence of mosquito breeding in half of the structures tested through mid-summer.

In summary, there are many ways in which stormwater BMPs can become mosquito breeding grounds if caution is not followed in their design, operation and maintenance. However, this section illustrates that the means exist to install BMPs that minimize the creation of mosquito habitat.

IV. References

Aichinger, C., 2004. Understanding the West Nile Virus. Woodbury Bulletin (newspaper opinion page), August 11, 2004. Contact Ramsey-Washington Metro Watershed District, North St. Paul, MN.

Andrews, W.J., J.R. Stark, A.L. Fong and P.E. Hanson, 1999. Ground-water quality along a flowpath in surficial outwash aquifer in the Upper Mississippi River Basin The influence of land use. Hydrological Science and Technology, 15(1-4):66-75. Special Issue: 4thUSA/CIS Joint Conference, November 7-10, 1999, San Francisco. American Institute of Hydrology.

Bäckström, M., 1999. Series of Papers in Licentiate Thesis, Luleå University of Technology.

Bäckström, M., 2002. Series of Papers in Doctorate Thesis, Luleå University of Technology.

Benson, C.H.; Abichou, M.A.; Bosscher, P.J. (1995) winter effects on hydraulic conductivity of compacted clay. Journal of geotechnical engineering. 121(1):69-79.

Buttle, J.M., 1990. Effect of suburbanization upon snowmelt runoff. Hydrol. Sci. Jour., 35(3):285-302.

Caraco, D. and R. Claytor, 1997. Stormwater BMP Design Supplement for Cold Climates. Center for Watershed Protection, Ellicott City, Maryland, USA.

Colbeck, S.C., 1978. Physical aspects of flow through snow. Advances in Hydroscience, 11: 165-206.

Colbeck, S.C., 1981. A simulation of the enrichment of atmospheric pollutants in snow cover runoff. Water Res. Research, 17(5): 1383-1388.

Colbeck, S.C., 1991. The layered character of snow covers. Rev. Geophys., 29(1):81-96.

Commonwealth of Virginia, 2003. Vector Control: Mosquitoes and Storm Water Management Stormwater Management Technical Bulletin No 8.

Duke, D., K. Patel, and B. Masek. 1999. “Widespread Failure to Comply with U.S. Storm Water Regulations for Industry-Part I: Publicly Available Data to Estimate Number of Potentially Regulated Facilities.” Environmental Engineering Science. Vol. 16(4).

Duke, D. and K. Shaver. 1999. “Widespread Failure to Comply with U.S. Storm Water Regulations for Industry-Part II: Facility-Level Evaluations to Estimate Number of Regulated Facilities.” Environmental Engineering Science. Vol. 16(4).

Granger, R.J., D.M. Gray and G.E. Dick, 1984. Snowmelt Infiltration to Frozen Soils. Canadian Journal of Earth Science, 21:669-677.

Hogland, W., M. Marques, and V. Karlaviciene. 2003. Stormwater Runoff From Industrial Areas and Pollution Transport. Proceedings from 1st International Conference on Urban Drainage and Highway Runoff in Cold Climate. Riksgränsen, Sweden.

Isabelle, P.S., L.J. Fooks, P.A. Kenny and S.D. Wilson, 1987. Effects of roadside snowmelt on wetland vegetation: An experimental study. Jour. of Envir. Management, 25:57-60.

Jeffries, D.S., 1988. Snowpack release of pollutants. National Water Research Institute (Burlington, Ontario, Canada), Report No. 88-06.

Marsalek, J., 2003. Road salts in urban stormwater: An emerging issue in stormwater management in cold climate. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.65-74.

Marsalek, J., G.L. Oberts, K. Exall and M. Viklander, 2003. Review of the operation of urban drainage systems in cold weather: Water quality considerations. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.1-11.

Marsalek, P.M., W.E. Watt, J. Marsalek, and B.C. Anderson, 2000. Winter flow dynamics on an on-stream stormwater management pond. Water Qual. Res. Jour. Canada,35(3): 505-523.

Marsh, P. and M-K. Woo, 1984. Wetting front advance and freezing of meltwater within a snow cover - 1. Observations in the Canadian Arctic. Water Res. Research,20(12): 1853-1864.

Maryland Department of the Environment (MDE), 2000. 2000 Maryland Stormwater Design Manual, Volumes I and II. Prepared by the Center for Watershed Protection and MDE.

Matheussen, B.V. and S.T. Thorolfsson, 2003. Estimation of snow-covered area for an urban catchment using image processing and neural networks. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.315-326.

Messer, D.F., 2003. Mosquitoes in Structural Stormwater BMPs: A Case Study. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Metzger, M.E., 2003. Mosquito Control Challenges Presented by Stormwater Treatment Devices in the United States. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Natural Resources Conservation Service (NRCS), 1984. Engineering Field Manual for Conservation Practices. U.S. Department of Agriculture, Washington, D.C.

Novotny, V., D.W. Smith, D.A. Kuemmel, J. Mastriano and A. Bartošová, 1999. Urban and Highway Snowmelt: Minimizing the Impact on Receiving Water. Wates Environment Research Foundation (WERF), Project 94-IRM-2.

Oberts, G.L., 2003. Cold climate BMPs: Solving the Management Puzzle. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.13-31.

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe, 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems, Metropolitan Council, Publication No.590-89-062a, 170 p.

Pitt, R. 2001. Methods for Detection of Inappropriate Discharges to Storm Drainage Systems: Background Literature and Summary of Findings. Tuscaloosa, AL Prince George's County Maryland. 2002. Prince George's County Bioretention Manual. Department of Environmental Resources.

Pronold, M., 2000. Administering the NPDES Industrial Storm Water Program in Proceedings: National Conference on Tools for Urban Water Resource Management and Protection. U.S. EPA, Office of Research and Development, EPA/625-R-00-001.

Sansalone, J.J. and S.G. Buchberger, 1996. Characterization of metals and solids in urban highway winter snow and spring rainfall-runoff. Trans. Res. Record, 1523:147-159.

Schueler, T., 2000. Pollutant Dynamics of Pond Muck. Watershed Protection Techniques, 1(2): 39-46. Center for Watershed Protection, Ellicott City, MD.

Schueler, T., C. Swann, T. Wright, and S. Sprinkle. 2004. Urban Subwatershed Restoration Manual No. 8: Pollution Source Control Practices, Version 1.0. Center for Watershed Protection. Ellicott City, MD.

Semadeni-Davies, A., 2003. Response surfaces for climate change impact assessments in urban areas. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.269-279.

Shaw, D. and R. Schmidt, 2003. Plants for Stormwater Design. Minnesota Polution Control Agency, 369 p.

St. Johns River Management District (SJRMD). 2001. Applicant's Handbook: Regulation of Stormwater Management Systems. Palatka, FL.

Stanek, S. (no date). West Nile Virus and Stormwater Management. Brochure prepared for the Minnehaha Creek Watershed District, Deephaven, MN.

UNESCO, 2000. Urban Drainage in Specific Climates: Vol.II. Urban Drainage in Cold Climates. ed. by S. Saegrov, J. Milina and S.T. Thorolfsson. IHP-V, Technical Documents in Hydrology, No. 40, Vol. II, Paris.

U.S. EPA Wetlands and West Nile Virus brochure

Wass, R.D., 2003. Mosquito Management Do's and Don'ts in an Engineered Arizona Treatment Wetland System. In Proceedings of the StormCon Conference of 2003, San Antonio, Texas. Published by Forester Communications, Santa Barbara, CA.

Westerström, G., 1984. Snowmelt runoff from Porsön residential area, Luleå, Sweden. In Proceedings of the Third International Conference on Urban Storm Drainage, Gothenburg, Sweden, June 4-8, 1984, pp. 315-324.

Wheaton, S.R. and W.J. Rice, 2003. Siting, design and operational controls for snow disposal sites. In Proceedings - Urban Drainage and Highway Runoff in Cold Climate, March 25-27, 2003, Riksgränsen, Sweden, pp.85-95.

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2004. Urban Subwatershed Restoration Manual No. 11: Unified Subwatershed and Site Reconnaissance: A User's Manual, Version 1.0. Center for Watershed Protection. Ellicott City, MD.

INVER GROVE HEIGHTS
Northwest Area

Chapter 7

Stormwater Sizing Criteria

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Stormwater Sizing Criteria

Chapter 7

Key Topics:	**stormwater sizing terminology, stormwater sizing criteria, recharge and infiltration standard, peak discharge standard, pretreatment standard, wetland bounce standard, redevelopment projects**

Contents

I. Introduction..... 3
II. Overview of NWA Stormwater Sizing Framework..... 3
III. Volume Control (Recharge and Infiltration) Standard..... 5
IV. Peak Discharge (Rate Control Standard)..... 5
V. Water Quality/Pretreatment Standard..... 6
VI. Wetland Bounce Standard..... 10
VII. Stormwater Sizing Redevelopment Projects..... 13
VIII. References..... 13

I. Introduction

This chapter outlines for stormwater professionals an approach for consistent sizing of stormwater management practices within the NWA that:

- **Perform Effectively**
  Manage enough runoff volume to address the problem it is intended to address.
- **Perform Efficiently**
  Manage just enough runoff volume to address the problem but not over-control it. More storage is not always better, and can greatly increase construction costs.
- **Be Simple to Administer**
  Be understandable, relatively easy to calculate with current hydrologic models, and workable over a range of development conditions and intensities. In addition, criteria should be clear and straightforward to avoid needless disputes between design engineers and plan reviewers when they are applied to development sites, while also eliminating any competitive disadvantages that are created when uniform regulations do not exist.
- **Promote Better Site Design**
  Be structured in a manner so that property owners have real incentives to reduce storage volumes (and costs) by applying better site design techniques (Chapter 4).

II. Overview of NWA Stormwater Sizing Framework

This section reviews the key stormwater sizing concepts and terminology used in the chapter and presents an overview of the framework for managing stormwater in the NWA.

Table 7.1 Review of Key Stormwater Sizing Terminology

Term	Definition:
Better Site Design	Better site design refers to the application of non-structural practices at new development sites to reduce site impervious cover, conserve natural areas, and use pervious areas to more effectively treat stormwater runoff. Also known as low impact development.
Design Storm	An engineering term for a single rainfall event with a defined intensity, duration and statistical recurrence interval ranging from 0.5 years up to 100 years. These single event storms are based on long-term rainfall data, and are used in hydrologic models to predict the peak discharges and runoff volumes associated with each type of storm. Unless otherwise indicated, all design storms in this chapter have a 24 hour duration and a Type 2 distribution.
Detention Time	Various definitions for detention time exist in hydraulic manuals and in help screens in computer models. For this Manual, a simple method of computing detention time is recommended. Detention time is equal to the length of time starting at basin full (for a specific design storm) and ending when either the basin is dry (filtration or infiltration) or the basin has attained normal water level (stormwater ponds or constructed wetlands).

Table 7.1 Review of Key Stormwater Sizing Terminology	
Term	**Definition:**
Hydrologic Soil Group	HSG is a USDA-NRCS designation given to different soil types to reflect their relative surface permeability and infiltrative capability. Group A soils have low runoff potential and high infiltration rates; Group B soils have moderate infiltration rates; Group C soils have low infiltration rates; and Group D soils have high runoff potential with very low infiltration rates and consist chiefly of clay soils (TR-55, 1986). See Chapter 8 for further discussion and classification of soils within the NWA.
Landlocked Basin	A basin that does not discharge under back-to-back 100-year, 24-hour rainfall events.
Pre-Development Conditions	The term pre-development can be interpreted many different ways. The City of Inver Grove Heights uses land cover conditions immediately preceding the current development project as the pre-development condition.
Regional Bains	Existing basins that the City has identified as being critical to the stormwater management plan and infrastructure of the Northwest Area of Inver Grove Heights. Grading within the HWL of these regional basins (defined by the critical event or 100-year 10-day snowmelt event) is generally prohibited. Potential encroachment on the basins storage volume or identified overflows shall be discussed with City Staff. A map of regional basin locations and overflows can be obtained from the City.
Sensitive Receiving Waters	The receiving waters in the NWA consist of landlocked wetlands which have been classified according to their sensitivity to stormwater impacts. Refer to Figure 2.10 and Table 2.4 for wetland management classifications and criteria.
Volume Control	Refers to volume of runoff which should be spread over pervious areas and otherwise infiltrated into the soil to promote groundwater recharge and maintain the natural hydrology of the system. The volume control standard for the NWA is: infiltrate the difference in the pre-and post-development volume for the 5-year 24-hour rainfall event.
Water Quality/Pretreatment	Generic term for the storage used to capture, treat and remove pollutants in stormwater runoff. It is normally expressed as a volume (watershed-inches or acre-feet).

Table 7.1 Review of Key Stormwater Sizing Terminology	
Term	**Definition:**
Worst-Case Design Event	The greatest runoff storage is used to detain the peak discharges of infrequent but very large storm events to predevelopment levels. The 100-year design storm, which has a statistical recurrence interval of occurring once in a hundred years is used by most communities. Extreme floods can cause catastrophic damage and even loss of life.

The goal of stormwater management is to provide effective control for each management scenario in order to produce post-development hydrology that most closely resembles the City's defined pre-development conditions at the development site. Each criterion defines a unique storage volume that should be managed at the site. Table 7.2 profiles the required sizing criteria for each of the stormwater management standards. The next four sections of the chapter describe each of the sizing criteria, including how they are calculated.

Table 7.2 Review of Stormwater Sizing Criteria	
Term	**Definition:**
Volume Control Standard	No increase in runoff volume from the site for the 5-year 24-hour rainfall event (3.6 inches).
Peak Discharge (Rate Control Standard)	Rate control for the 2-, 10- and 100-year 24-hour rainfall events.
Water Quality / Pretreatment Standard	The amount of pretreatment required depends upon both the amount of impervious area and type of drainage system that is being used. Figure 7.1 should be used to clarify the type of drainage system that is being utilized and decide when structural pretreatment devices are necessary to meet the 85% TSS removal requirement.
Wetland Bounce	No increase in bounce for Manage 1 Wetlands and up to a half a foot of bounce for Manage 2 Wetlands for the 100-year 24-hour rainfall event.

III. Volume Control (Recharge and Infiltration) Standard

The intent of this sizing criterion is to maintain the pre-development hydrology of the NWA, a landlocked system, as closely as possible. Under natural conditions, the amount of recharge that occurs at a site is a function of slope, soil type, vegetative cover, precipitation and evapotranspiration. Sites with natural ground cover, such as forest and meadow, typically exhibit higher recharge rates, less runoff and greater transpiration losses than sites dominated by impervious cover. Since development increases impervious cover, there is a net decrease in recharge and a corresponding increase in stormwater runoff volume.

The recharge volume is determined by taking the difference between the pre-development volume for the 5-year 24-hour event and the post-development volume for the same event. Recharge can be achieved either by a structural BMP (e.g. infiltration, bioretention, vegetated swale), better site design techniques, or a combination of both.

For additional information on how this standard was established see the following report: City of Inver Grove Heights – Northwest Area Surface Water Modeling Report, August 2006.

IV. Peak Discharge (Rate Control Standard)

The intent of this sizing criterion is two-fold: controlling peak discharge for the 2-year 24-hour event prevents habitat degradation and erosion in urban streams (open ditch flow) and controlling peak discharge for the 10- and 100-year 24-hour events prevents flood damage to conveyance systems and infrastructure and reduces minor flooding caused by overbank floods.

Channel Protection Volume (2-year 24-hour Rate Control)

Historically, 2-year 24-hour peak discharge control has been the most widely applied local criteria to control channel erosion in Minnesota, and many communities continue to use it today. More specifically, 2-year peak control seeks to keep the post-development peak discharge rate for the 2-year 24-hour rainfall event at pre-development rates. The reasoning behind this criterion is that the bankful discharge for most streams has a recurrence interval of between 1 and 2 years, with approximately 1.5 years as the most prevalent (Leopold, 1964 and 1994), and maintaining this discharge rate should act to prevent downstream erosion.

Overbank Flood Volume (10- and 100-year 24-hour Rate Control)

Most local reviewing authorities establish an overbank design storm that is matched with the same design storm used to design open channels, culverts, bridges, and storm drain systems. Most localities in Minnesota require that post-development peak discharge rates from the 10-year and 100-year, 24 hour design storm event be controlled to predevelopment rates.

In general, the storage volume needed to manage the 100-year return design storm is much greater than the 10-year design storm. Modeling has shown that control of the 10-year storm coupled with control of the 100-year storm effectively attenuates storm frequencies between these two events (e.g., the 25-year storm).

V. Water Quality/Pretreatment Standard

As stormwater runoff travels across the landscape, it picks up pollutants associated with urban and agricultural practices, transporting them to the nearest downstream receiving water body. For example, runoff from parking lots picks up oil and grease dripped from cars, asbestos from worn brake linings, and zinc from tires. Pesticides, herbicides and fertilizers are washed off from landscaped areas, and soils are washed away from construction sites. The most common pollutants associated with stormwater runoff include: oils and greases, metals, sediments, oxygen-demanding substances, nutrients, toxic organic compounds, fecal coliform, bacteria and pH. To reduce the amount of pollutants found in stormwater runoff make sure you are practicing proper pollution prevention techniques by reviewing Chapter 5 of the manual.

In a traditional pipe and pond scenario, these pollutants find their way to lakes, wetlands and streams. In a landlocked system, such as the NWA, where there is no outlet, these stormwater pollutants can end up in the most downstream water body or depression and sometimes in the groundwater system as the stormwater is retained and allowed to infiltrate. The pretreatment of stormwater prior to infiltration is important for the following reasons:

- The infiltration of significant volumes of stormwater runoff may contribute to the pollution of groundwater resources
- The maintenance requirements of stormwater infiltration practices are dependent upon the amount of sediment and other pollutants being delivered to the practice

In addition, pretreatment can be used to dampen the effects of high or rapid inflow, dissipate energy levels of stormwater runoff and provide additional storage.

Methods of Pretreatment

There are a number of pretreatment practices available to the design engineer for treating stormwater runoff prior to infiltration. In general, pretreatment practices should be included in the treatment train approach to stormwater management and be designed to handle the first flush of runoff generated during a precipitation event. The Designer shall ensure that the design of pretreatment practices complies with the NPDES Stormwater Permitting Program.

Non-Structural Pretreatment Practices/Source Reduction or Pollution Prevention

Source reduction is an effective non-structural way of controlling the amounts of pollutants entering stormwater runoff. A wide range of pollutants are washed off of impervious surfaces during runoff events. Removing these contaminants from the urban landscape prior to precipitation can effectively limit the amounts of pollutants contained in the stormwater runoff. Source reduction can be accomplished by a number of different processes including:

- Limiting applications of fertilizers, pesticides and herbicides;
- Periodic street sweeping to remove trash, litter and particulates from streets;
- Collection and disposal of lawn debris;
- Periodic cleaning of catch basins;
- Elimination of improper dumping of used oil, antifreeze, household cleaners, paint, etc. into storm drains;
- Identification and elimination of illicit cross-connections between sanitary sewers and storm sewers.

For more information on source reduction or pollution prevention techniques see Chapters 5 and 8.

Structural Pretreatment Practices

- Filtration Systems – Use some combination of a granular filtration media such as sand, soil, organic material, carbon or a membrane to remove constituents found in runoff.
- Vegetated Systems – Designed to convey and treat shallow flow or sheet flow runoff. Includes grass channels (biofilters), dry swales, wet swales and filter strips.
- Proprietary settling/swirl chambers – Include systems that remove particulates and litter prior to discharge to BMP that do not fit in any of the above categories (e.g. catch basin inserts, hydrodynamic devices and filtration systems).
- Stormwater Ponds/Detention Systems – Capture a volume of runoff and temporarily retain that volume for subsequent release. Detention systems do not retain a significant permanent pool of water between runoff events.

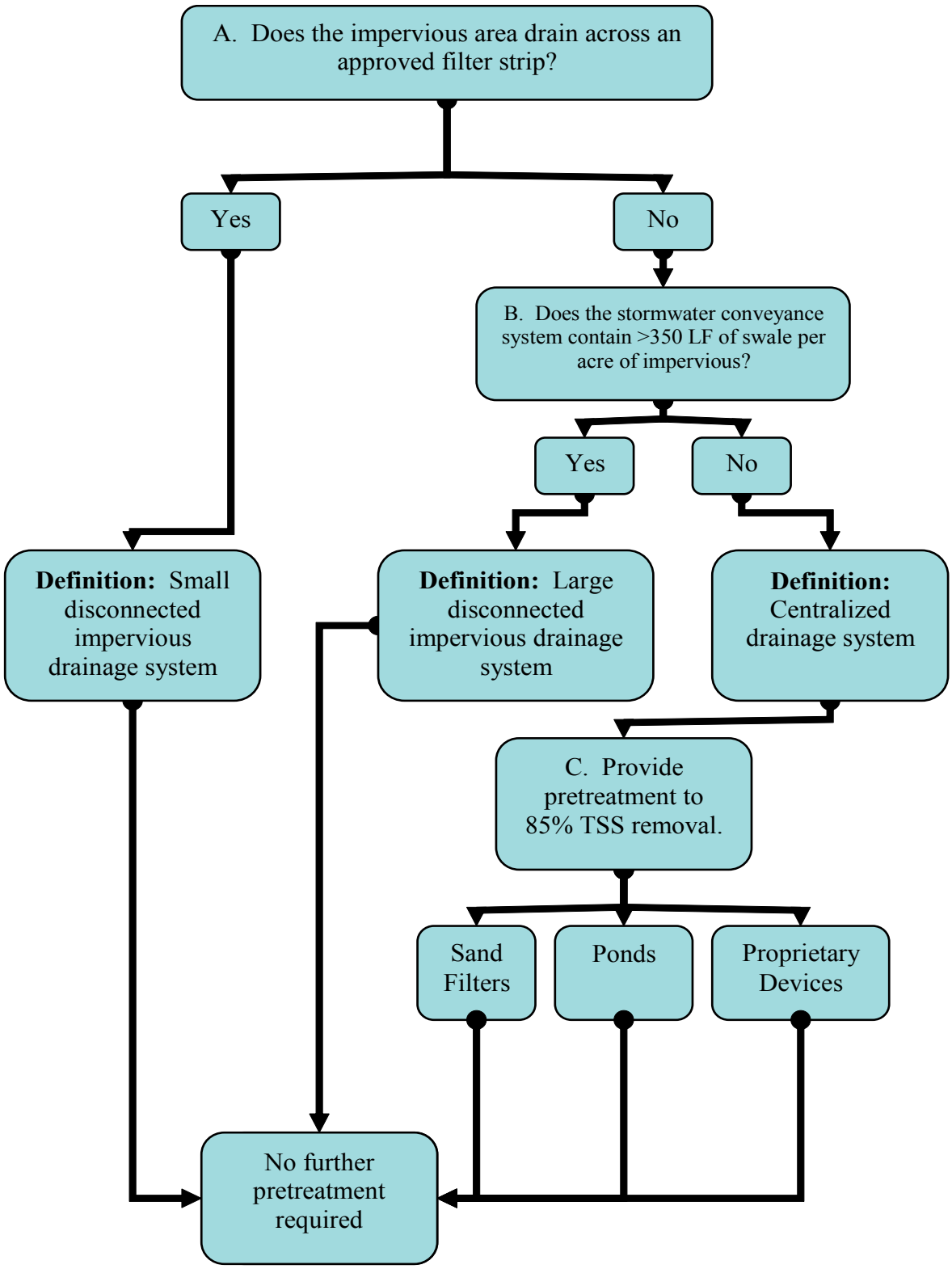
For more detailed information on the design and construction of structural pretreatment practices see Chapter 8.

Applying Structural Pretreatment Practices in the Northwest Area

Various land use settings inherently provide for more pretreatment than other landuse settings. For example: stormwater runoff from residential rooftops that discharges to the rear-yard area receives more pretreatment than residential rooftops that drain directly to the stormwater system. Therefore, the pretreatment requirements that are required for each site will depend on the site characteristics and grading plan.

Every infiltration practice will require some pretreatment to extend the life of the practice. The amount of pretreatment required depends upon both the amount of impervious area and type of drainage system that is being used. Figure 7.1 should be used with the following text to define the type of drainage system

Figure 7.1 Pretreatment Flow Chart



that is required and decide where structural pretreatment devices are necessary. The three types of drainage systems are 1) “small disconnected drainage system”, 2) “large disconnected drainage system” or 3) “centralized drainage system”. Drainage systems 1 and 2 do not require any additional pretreatment devices because pretreatment is met through disconnection of impervious surfaces. Drainage system 3 requires the use of a BMP to accomplish 85% TSS removal. Design requirements for these BMPs are discussed in further detail in Chapter 8.

A. Identify all impervious areas that flow over an approved filter strip.

Definition - Approved Filter Strip
There are two general settings in which pretreatment may be provided by filter strip. Areas that fall under this category do not need to provide additional pretreatment. Filter strip pretreatment for settings not covered here require pre-approval by the City Engineer. More information about filter strips can be found in chapter 8.

- Impervious areas less than 0.25 acre that drain across grass filter strips with the minimum dimensions shown in Table 7.3 meet pretreatment requirements and no further pretreatment is required. Use Table 7.3 to find the necessary length of filter strip. The purpose of this drainage system distinction is to recognize pretreatment for disconnected impervious areas such as rooftops that drain through yards, crowned driveways, patios, sheds and other small areas of impervious that drain over large pervious areas before entering the stormwater system.

Table 7.3 Filter Strip Sizing

Parameter	Impervious Parking Lots & Streets				Rooftops			
Inflow Approach Length [ft.]	0-35		>35		0-35		>35	
Filter Strip Slope	<2%	2-5%	<2%	2-5%	<2%	2-5%	<2%	2-5%
Filter Strip Minimum Length	10’	15’	20’	25’	10’	12’	15’	18’

- Filter strips may be used as pretreatment for linear infiltration practices such as infiltration trenches along roadways. The roads, filter strip, and infiltration practices must be designed to allow sheetflow from the road through the filter strip before the runoff enters the infiltration practice. If runoff is concentrated and channelized then the drainage area is considered connected and additional pretreatment is necessary.

To establish that the impervious area falls into this category, it is helpful to examine the impervious/pervious interface. If more than 0.25 acres of impervious surface drains to any one point, then the impervious surface is NOT a small disconnected impervious drainage system. The dimensions in Table 7.3 must also be met.

- Small disconnected impervious areas must be identified on the site plan to be excluded from sizing of pretreatment facilities.

B. Identify all areas that are part of a large disconnected impervious drainage system

Definition – Large Disconnected Drainage System
If the drainage area to the infiltration BMP is conveyed through vegetated swales or buffers that meet the specified criteria, the BMP is considered a large disconnected drainage system.

- Large disconnected drainage systems meet the pretreatment requirement through filtering in vegetative

channels but must contain at least 350 LF of channel per acre of impervious. Large disconnected drainage systems generally exist in areas developed with rural road cross-sections where stormwater is conveyed through grassed channels and/or swales.

- ► Large disconnected drainage areas must be shown on the site plan to be excluded from sizing of pretreatment facilities.

C. Design Filter, Pond, or Proprietary device to remove 85% TSS for remaining impervious drainage area. The remaining impervious area is classified as a centralized drainage system. Filters, ponds and other BMPs are discussed in detail in Chapter 8.

- ► Identify the remaining impervious area on the site plan. This is the runoff area that should be used to size pretreatment facilities.
- ► Use the following sizing criteria for pretreatment facilities. Other practices may be pre-approved at the city engineer's discretion.

Sand Filters

An operation and maintenance plan must be developed to ensure that sand filters are adequately maintained to provide pretreatment.

Recommendations:

- ► Use an 18-inch thick filter bed
- ► Use a sand media with a coefficient of permeability of 3.5 ft/day (1.75 in/hr)
- ► Set the maximum head on the filter to 6 feet
- ► Drain the filter bed within 72 hours, 48 hours if need to meet MPCA permit requirements

The filter area for a sand filter that has the recommended characteristics can be sized based on the following equation.

$$\mathbf{A_f = 0.0476 * V_{wq}}$$

The filter area for a non-standard filtration system is sized using the following equation (based on Darcy's Law).

$$\mathbf{A_f = (V_{wq})\ (d_f) \,/\, [(k)\ (h_f + d_f)\ (t_f)]}$$

Where:

- $\mathbf{A_f}$ = Surface area of filter bed ft^2
- $\mathbf{V_{wq}}$ = Water quality volume (ft^3)
- $\mathbf{d_f}$ = Filter bed depth (ft)
- **k** = Coefficient of permeability of filter media (ft/day)
- $\mathbf{h_f}$ = Average height of water above filter bed (ft)
- $\mathbf{t_f}$ = Design filter bed drain time (days)

Ponds

- ► Design to NURP standards
- ► Permanent Pool Volume =1800 CF/Acre of Drainage
- ► Permanent Pool Depth = 3' – 10'

Proprietary Devices

- ► Must meet 85% TSS removal efficiency using standard particle size distribution
- ► Must have a means to remove soils and floatables
- ► Must have a maintenance plan for removing sediments

VI. Wetland Bounce Standard

Until recent years, wetlands were viewed as wastelands that were better drained or filled. It is estimated Minnesota has lost nearly 42 percent of its original wetland acreage (MN SWAG, 1997). Wetlands are now recognized as performing many important watershed functions and services, and their direct disturbance is closely regulated.

Stormwater runoff has the potential to impact the soils, flora and fauna, and water quality of wetlands. Disturbance to wetland hydrology can cause changes in the character of the ecosystem including species composition and richness, primary productivity, organic deposition and flux, and nutrient cycling. Naturally occurring quantities of runoff with seasonal fluctuations are essential for the maintenance of a wetland, and moderate amounts of nutrients and sediment in the runoff can increase a wetland's productivity. However, excessive stormwater runoff has the potential to alter the hydrology, topography, and the vegetative composition of a wetland (U.S. EPA, 1993). For example, an increased frequency and duration of inundation can degrade native wetland plant communities or deprive them of their water supply.

Stormwater runoff increases the temperature, conductivity, nutrients, metal and sediment loads to wetlands. Changes in wetland water quality alter the nature of the plant community, encouraging invasive species, and reducing sensitive species that are preferred by fish, mammals, birds, and amphibians for food and shelter (U.S. EPA, 1993).

Stormwater runoff inputs can exceed the water depths and frequency/duration of inundation prevalent in natural wetlands, leading to a die-out of vegetative species. Deposition of sediment carried by urban stormwater can have the same effect, causing replacement of diverse species with monotypes of reed canary grass or cattails, which are much more tolerant of sedimentation and fluctuating water levels. Schueler (2000b) reported that invasive or aggressive plant species are favored when water level fluctuation (WLF) is high (e.g., reed canary grass). The result is low vegetative diversity and lower quality wildlife habitat values (MN SWAG, 1997). A modest change in WLF sharply decreases plant species richness, and amphibian species richness a study in the Pacific Northwest (Horner, et al. 1996).

Not all wetlands respond in the same way to the impact of stormwater runoff. In the context of this manual, wetlands can be defined as Susceptible or Non-susceptible to stormwater runoff, based on the MN SWAG (1997) wetland classification scheme. This classification provides a useful framework for managing stormwater inputs to different types of wetlands.

Highly susceptible wetland communities can be composed of dozens of plant species. Table 7.4 presents the MN SWAG classification of wetland types according to their presumed susceptibility to degradation by stormwater. Given this diversity of wetland types, it is not surprising that wetlands have a broad range of tolerance to stormwater runoff input. Some wetlands (i.e. calcareous fens) are sensitive to any disturbance and will show signs of degradation with even low-level inputs of urban stormwater. Note that Susceptible Wetlands are defined as highly and moderately susceptible in Table 7.4 and Non-susceptible Wetlands are defined as slightly and least in the table.

Table 7.4: Susceptibility of Wetland Types to Degradation by Stormwater Input			
Highly Susceptible Wetland Types[1]	**Moderately Susceptible Wetland Types[2]**	**Slightly Susceptible Wetland Types[3]**	**Least Susceptible Wetland Types[4]**
► Sedge Meadows ► Open Bogs ► Coniferous Bogs ► Calcareous Fens ► Low Prairies ► Coniferous Swamps ► Lowland Hardwood Swamps ► Seasonally Flooded Basins	► Shrub-carrs[a] ► Alder Thickets[b] ► Fresh (Wet) Meadows[c,e] ► Shallow Marshes[d,e] ► Deep Marshes[d,e]	► Floodplain Forests[a] ► Fresh (Wet) Meadows[b] ► Shallow Marshes[c] ► Deep Marshes[c]	► Gravel Pits ► Cultivated Hydric Soils ► Dredged Material / Fill Material Disposal Sites

Notes: Pristine wetlands are those that show little disturbance from human activity. There will always be exceptions to the general categories listed above. Use best professional judgment.

1. Special consideration must be given to avoid altering these wetland types. Inundation must be avoided. Water chemistry changes due to alteration by stormwater impacts can also cause adverse impacts. Note: All scientific and natural areas and pristine wetlands should be considered in this category regardless of wetland type.

2a, 2b, 2c. **Can tolerate inundation from 6 inches to 12 inches for short periods of time. May be completely dry in drought or late summer conditions**.

2d. Can tolerate +12" inundation, but adversely impacted by sediment and/or nutrient loading and pro- longed high water levels.

2e. Some exceptions.

3a. Can tolerate annual inundation of 1 to 6 feet or more, possibly more than once/year.

3b. Fresh meadows which are dominated by reed canary grass.

3c. Shallow marshes dominated by reed canary grass, cattail, giant reed or purple loosestrife.

4. These wetlands are usually so degraded that input of urban stormwater may not have adverse impacts.

Source: State of Minnesota Storm-Water Advisory Group, 1997

The following stormwater sizing criteria are required to protect wetlands from the indirect impact of stormwater runoff:

Maintain the hydroperiod of susceptible wetlands following development to prevent detrimental impacts. The wetland types found in the NWA are identified in the Natural Wetland Resource Inventory (NRI) Report (2004). The NRI also assigns management classifications based on the susceptibility of these wetland types to stormwater impacts ranging from 1 (high susceptibility to stormwater bounce) to 4 (low susceptibility to stormwater bounce). This report also provides recommended buffer widths and phosphorus pretreatment requirements based on the wetland classifications. Table 7.5 summarizes these wetland management standards.

The term "existing" in this chart means the existing hydrologic conditions. If there have been recent significant changes in conditions, it means the conditions that established the current wetland. Designers then model the effect of runoff discharge from the site on the wetland to ensure they conform to the storm bounce and inundation duration guidelines standards set forth in Table 7.5 using infiltration, extended detention, diversion or other methods.

Table 7.5 Wetland Management Standards			
Management Classification	Buffer Strip (feet) Slopes <15%	Structural Setback from Edge of Buffer (feet)	Stormwater Quantity Requirement
Manage 1	60	10	Storm Bounce - Maintain HWL at or below existing conditions for 100-year storm
Manage 2	30	10	Storm Bounce - Maintain HWL at or below existing conditions plus 0.5 feet for 100-year storm
Manage 3	20	10	no requirement
Manage 4	15	10	no requirement

Additional guidance on BMP design to protect wetlands is offered below:

- BMPs such as stormwater wetlands, infiltration systems, and bioretention are encouraged to treat runoff prior to discharge to a wetland
- Direct pipe outfalls to wetlands should be restricted (e.g., not allowed, allowed if energy dissipated, or routed through pre-treatment system).
- Stormwater should be routed around sensitive wetlands using a diversion or bypass system.
- Constrictions at wetland outlets should be avoided.
- Natural wetlands should not be used for stormwater treatment, unless they are severely impaired and construction would enhance or restore wetland functions; if natural wetlands are used in this manner, 7050 establishes the sequence of avoid, minimize and compensatory replacement
- The discharge of untreated stormwater to a wetland is prohibited.

VII. Evaluation of Regional Basins

During the development of the Inver Grove Heights NWA Stormwater Management Plan a number of regional depressions, or basins, were identified as being critical to the success of the plan. These basins, most of which are landlocked, currently capture stormwater runoff for retention and infiltration. In order to preserve the hydrologic balance of this system under post-development conditions, these regional basins shall be preserved and operated in the same manner they are functioning today.

In order to maintain their current function in the landscape, the regional basins should be subject to the same drainage characteristics and should be protected from any grading or construction activities which may alter the storage volume below the HWL or the infiltration capacity of the soils. In addition, the natural overflows or City identified overflow areas shall be protected from construction activities.

If the proposed development activity proposes one of the following, the Permit Applicant shall consult with City Staff immediately:

1. Grading and/or filling the storage volume of a regional basin below the HWL;

2. Modifying the hydrologic boundary so that the drainage area to a regional basin is larger than the existing conditions drainage area; or

3. Grading or otherwise impacting the natural overflow of a regional basin or the overflow area identified in the City of Inver Grove Heights Overflow Contingency Plan.

VIII. Stormwater Sizing for Redevelopment Projects

Small redevelopment sites can pose special challenges for stormwater design, given their small size, intensive use, and compacted soils. All redevelopment projects in the NWA will be required to meet the stormwater management standards identified in Table 7.2.

IX. References

Preliminary Data Summary of Urban Stormwater Best Management Practices EPA-821-R-99-012, August 1999

Metropolitan Council, Barr – Filtration Systems, Surface Sand Filters

U.S. Department of Transportation. Federal Highway Administration. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Fact Sheet – Surface Sand Filters.

Georgia Stormwater Management Manual. Volume 2. 3.3.4 Underground Sand Filters

Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices. 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

INVER GROVE HEIGHTS
NWA

Chapter 8

Details of Stormwater Best Management Practices (BMPs)

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Details of Stormwater Best Management Practices (BMPs)

Chapter 8

Key Topics: guidance materials for recommended BMPs, BMP fact sheets, BMP guidance documents, and design factors

Contents

I. Introduction..... 5
II. Fact Sheets and Design Guidance..... 5
III. NWA Design Influences..... 6
IV. Design Guidance - Overview..... 8
V. The Role of Pre-Treatment..... 9
VI. The Importance of Maintenance..... 11
VII. Fact Sheets..... 12
- Pollution Prevention - Residential Practices..... 13
- Pollution Prevention - Municipal Practices..... 15
- Pollution Prevention - Industrial & Commercial Practices..... 17
- Better Site Design - Overview..... 21
- Better Site Design - Residential Streets & Parking Lots..... 23
- Better Site Design - Lot Development..... 25
- Better Site Design - Conservation of Natural Areas..... 27
- Temporary Construction Sediment and Erosion Control..... 29

VIII. Guidance Documents..... 35
- Green Roofs..... 36
  - A. Suitability..... 38
  - B. Major Design Elements..... 40
  - C. Construction Details..... 41

D. Construction Specifications..... 42
E. Operation and Maintenance..... 44
F. Design Procedure..... 44
G. Additional Resources..... 45
Rainwater Harvesting..... 46
A. Suitability..... 48
B. Major Design Elements..... 51
C. Construction Specifications..... 52
D. Operation and Maintenance..... 52
E. Links to Other Manuals..... 53
F. References..... 53
Pervious Surfaces..... 54
A. Suitability..... 56
B. Major Design Elements..... 58
C. Construction Specifications..... 59
D. Operation and Maintenance..... 60
E. Additional Resources..... 62
Filtration..... 64
A. Suitability..... 66
B. Major Design Elements..... 70
C. Construction Specifications..... 72
D. Operation and Maintenance..... 75
E. References..... 86
Bioretention..... 88
A. Suitability..... 90
B. Major Design Elements..... 97
C. Construction Specifications..... 100
D. Operation and Maintenance..... 101
E. Design Procedure..... 103
F. Links to Other Manuals..... 109
G. References..... 109
Infiltration Practices..... 110
A. Suitability..... 112
B. Major Design Elements..... 115
C. Construction Specifications..... 118
D. Operation and Maintenance..... 119
E. Design Procedure..... 123
F. Links to Other Manuals..... 131
G. References..... 131
Stormwater Ponds..... 132
A. Suitability..... 134

B. Major Design Elements 137
C. Construction Specifications 142
D. Operation and Maintenance 142
E. Design Procedure 147
F. Links to Other Manuals 154
G. References 154
Stormwater Wetlands 156
A. Suitability 158
B. Major Design Elements 161
C. Construction Specifications 164
D. Operation and Maintenance 164
E. Design Procedure 168
F. Links to Other Manuals 174
G. References 175
Soil Amendments 176
A. Suitability 178
B. Major Design Elements 180
C. Construction Specifications 181
D. Operation and Maintenance 181
E. Design Procedure 182
F. References 185
Supplemental BMPs - Chemical and Biological Treatment 186
Supplemental BMPs - Filtration Devices 188
Supplemental BMPs - Hydronamic Devices 190

I. Introduction

Stormwater BMP design is governed by two fundamental influences: regulatory compliance and technical performance. This manual has taken design procedures recommended in the Minnesota Stormwater Manual and customized them to reflect the unique conditions of the NWA and the focus on infiltration in this landlocked basin system.

II. Fact Sheets and Design Guidance - General

The fact sheets and design guidance document information is presented in treatment train order:

Pollution Prevention

- ► Residential Practices Fact Sheet
- ► Municipal Practices Fact Sheet
- ► Industrial & Commercial Practices Fact Sheet

Better Site Design

- ► Overview Fact Sheet
- ► Residential Streets and Parking Lots Fact Sheet
- ► Lot Development Fact Sheet

Temporary Construction Erosion and Sediment Control

- ► Fact Sheet

Green Roofs

- ► Fact Sheet
- ► Guidance Document

Pervious Surfaces

- ► Fact Sheet
- ► Guidance Document

Rainwater Harvesting

- ► Fact Sheet
- ► Guidance Document

Bioretention Practices

- ► Fact Sheet
- ► Guidance Document

Filtration Practices

- ► Fact Sheet
- ► Guidance Document

Infiltration Practices

- ► Fact Sheet
- ► Guidance Document

Stormwater Ponds

- ► Fact Sheet
- ► Guidance Document

Stormwater Wetlands

- ► Fact Sheet
- ► Guidance Document

Supplemental BMPs

- ► Filtration Devices Fact Sheet
- ► Hydrodynamic Devices Fact Sheet
- ► Chemical & Biological Treatment Fact Sheet

Soil Amendments

- ► Fact Sheet
- ► Guidance Document

The two-page fact sheets can be used as stand-alone education pieces or as introductions to the more detailed design guidance sheets. These summary fact sheets present a description of the BMP, plus overview information on suitability, key design considerations (benefits and limitations), performance information, and site factors. Additional design Guidance Sheets are presented for the structural BMPs (Green Roofs, Rainwater Harvesting, Pervious Surfaces, Bioretention Practices, Filtration Practices, Infiltration Practices, Stormwater Ponds, Stormwater Wetlands and Soil Amendments). Each section of design guidance consists of discussions of BMP suitability, major design elements, design procedures, O&M procedures, cost determinations, graphics and references.

III. NWA Design Influences

Stormwater BMP design is governed by two fundamental influences: regulatory compliance and technical performance. This manual has taken design procedures recommended in the Minnesota Stormwater Manual and customized them to reflect the unique conditions of the NWA and the focus on infiltration in this landlocked basin system.

Regulatory

Minimum stormwater management requirements for most new construction are specified at the state level by the MPCA General Stormwater Permit for Construction Activities (MNR100001), often referred to as the construction general permit. For the NWA, additional requirements are outlined in the NWA Planned Unit Development (PUD) Overlay District and in Inver Grove Heights City Code, (Section 430 - Storm Water Management). Design criteria specifically required by City Code, the PUD or MPCA Permit are identified in the text of the following sections with the term REQUIRED. Of course, if the indicated rule does not apply in a given situation, neither do the associated requirements.

City Code, the PUD and the MPCA construction general permit allow specific permanent stormwater management BMPs. The focus in the NWA is on infiltration/filtration areas, but there may be circumstances requiring wet detention or regional ponds. These BMPs must meet the design requirements found in these

RESOLVING DESIGN CONFLICTS

When designing a BMP, it is possible that the site conditions will lead to conflicting regulatory or technical requirements. Designers and regulators that find themselves in such a situation should use the following guide to resolve these conflicts:

REQUIREMENT vs. REQUIREMENT: Contact local water management authority to discuss solutions. Usually the strictest requirements will satisfy both regulations.

REQUIREMENT vs. TECHNICAL RECOMMENDATION: Follow regulatory requirement.

TECHNICAL RECOMMENDATION vs. TECHNICAL RECOMMENDATION: Use best professional judgment in consultation with local authorities.

documents. Alternative stormwater treatment BMPs are allowed if they can demonstrate by calculation, design, or other independent methods that they will achieve approximately 85% removal of total suspended solids on an annual average basis. The removal efficiency should be based on all particle sizes from the Midwest particle size distribution found in the National Urban Runoff Program (NURP) pond study completed in 1983. The permit application REQUIRES the submission of a Storm Water Management Plan which includes a mitigation plan, monitoring requirements, and performance goals for the proposed BMP, specifically:

- Existing site map showing topography and delineating water bodies at the site
- Site construction plan indicating erosion and sediment control measures and construction sequencing
- Calculations, plans, and specifications
- A description of the drainage area tributary to the alternative BMP
- Mitigation plan for replacement of the alternative BMP in the event that the monitoring plan show that the BMP fails to remove 85% of the Total Suspended Solids on an annual average basis from the site runoff.
- Final Site plan including landscaping and drainage plans
- Post construction monitoring plan

It must be understood that **additional local, state, or federal regulations may apply to a particular stormwater management practice**, although they are not specifically indicated in this Manual. These additional requirements must be identified and satisfied in all BMP construction projects.

Technical

In addition to the requirements outlined in applicable regulations, there are technical or engineering principles that are not specified in code but which can significantly affect BMP performance. Within this category of non-stipulated, performance-based design principles, a further distinction may be made between *essential design standards*, identified in this Manual with the term HIGHLY RECOMMENDED, which are critical for proper functioning, and *design recommendations*, identified as RECOMMENDED, which are valuable for enhancing BMP performance but not strictly crucial to the design.

IV. Design Guidance - Overview

BMP Suitability

This first section contains general suitability information for each BMP and its role in the treatment train. Information includes major features of each BMP "variant" or practice variation. In addition to the typical design elements, this guidance includes discussions of cold climate design modifications, retrofit feasibility, water quantity and water quality treatment, and limitations of the practice.

Design Elements

Site conditions often dictate the selection of BMPs. Therefore, this section allows site owners and designers to conduct a preliminary screening to learn if the BMP is feasible, based on specific site conditions. Major design elements of each BMP are described.

Construction Details and Specifications

Typical details for each structural BMP, and some variants, are included as AutoCAD Version 2000 DWG file format in Appendix A. Each document includes plan and profile views, plus important details, such as inlet structures, cross-sections and outlet structures. The notes section includes information that designers should consider incorporating into their technical specifications. Designers are encouraged to research other excellent water resources related design documents prepared by Minnesota agencies:

Supplemental Environmental Design Documents for Public Watercourse Crossings, June, 2005
Minnesota Department of Natural Resources

CADD Standards, Minnesota Department of Transportation
CADD Standards Software Libraries
Mn/DOT Standard Plans, English Subject Index - Mn/DOT

Mn/DOT Standard Specifications for Construction
Mn/DOT Standard Specifications for Construction - 2000 and 1995 (Metric) Editions

*Mn/DOT Drainage Manua*l, 2005
Hydraulics External Home

Mn/DOT Specifications for Erosion Control (draft)
Office of Environmental Services

Erosion Control Handbook for Local Roads, 2003. Minnesota Local Technical Assistance Program (LTAP)

Best Practices Handbook on Roadside Vegetation, 2000. Minnesota Local Technical Assistance Program
Publications - Minnesota LTAP

Plants for Stormwater Design, Minnesota Pollution Control Agency
Plants for Stormwater Design -- Minnesota Pollution Control Agency

Operation and Maintenance

Long term performance of BMPs is ensured with proper operation and regular maintenance. Therefore, it is REQUIRED that site designers communicate how to maintain the BMP in an Operation and Maintenance (O&M) Plan. Owners and maintenance staff will be able to reference this plan when they have questions about sediment removal, valve operation, or capacity for future site expansion. Contents of an O&M

plan could include: as-built plans, operating instructions for weirs and valves, vegetation list, vegetation maintenance schedule, and maintenance checklists.

In this section operation and maintenance is discussed in terms of phasing:

- ► Design Phase Maintenance Considerations
- ► Construction Phase Maintenance
- ► Post-Construction Operation and Maintenance

Suggested checklists for construction phase maintenance and post-construction phase O&M are contained in Appendix D.

Construction and Maintenance Costs

The cost considerations section of the Guidance Sheets are set up to guide users through developing a cost to construct, operate and maintain the BMPs selected for their sites. A detailed cost estimation procedure, including both construction and O&M costs, is contained in the design guidance. A design elements table includes major features of the specific BMP. The list does not include construction activities that are common to all aspects of a construction project, such as mobilization, traffic control and site erosion and sediment control. Estimators are encouraged to include these items for BMP construction projects that are not associated with a larger site development or redevelopment project. The worksheets contained in Appendix F can also be used to prepare a detailed cost estimate.

Design Procedures

Detailed design guidance for each BMP includes step by step procedures. The steps refer the designer back to better site design procedures in Chapter 4 so that the space dedicated to stormwater management within any site is optimized for both location and size. Designers are encouraged to fit a stormwater practice into the space available, and then check the hydraulics to determine if the size is adequate for managing the volume associated with the 5-year 24-hour rainfall event. This procedure is purposely intended to optimize the space available for BMPs on each site.

Figure 8.1 lays out the general procedural steps recommended in this manual. Specific steps, based on this general procedure, are detailed in the design guidance sheets.

V. The Role of Pre-Treatment

Many of the stormwater practices discussed in this manual require pre-treatment as described in Chapter 7. The reason for this requirement is the necessity to keep a BMP from being overloaded, primarily by sediment, and the protection of groundwater resources from pollution. Pre-treatment can also be used to dampen the effects of high or rapid inflow, dissipate energy, and provide additional storage. All of these ancillary benefits help BMP performance.

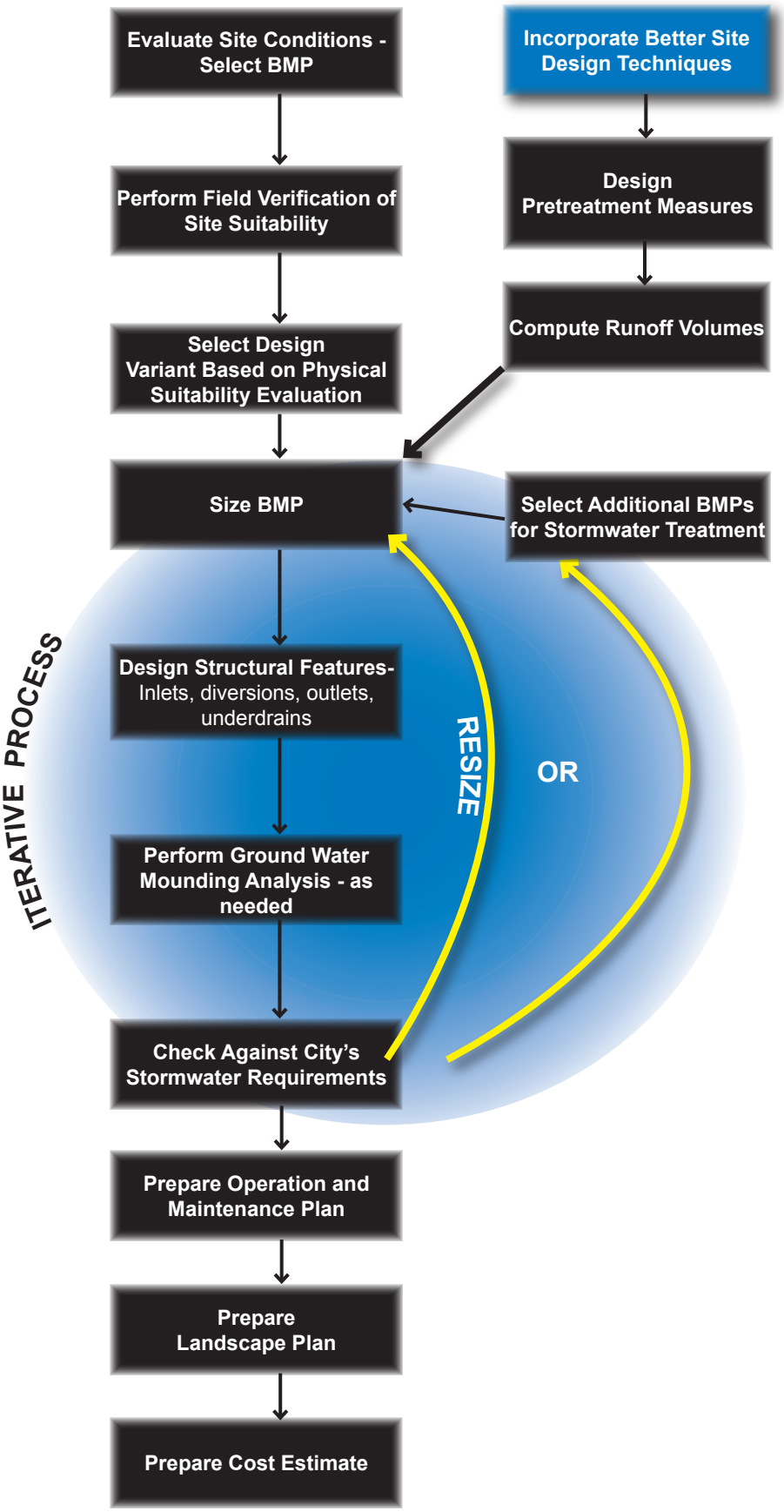
Methods of Pre-Treatment

There are many ways to pre-treat runoff prior to discharging it into an infiltration BMP including:

- ► Forebays – settle sediments from water before further treatment in stormwater pond
- ► Small sediment basins – settle sediment from water before further treatment by another BMP
- ► Street/parking lot sweeping – remove pollutants from an impervious surface draining to a BMP
- ► Proprietary settling/swirl chambers – remove particulates and litter prior to a BMP

Although “pre-treatment” does not appear as a BMP group in this chapter, many of the listed BMPs can perform in such a role.

Figure 8.1 Design Procedures Flowchart



VI. The Importance of Maintenance

Over time, watershed organizations, homeowner associations and municipalities have learned that 20 years of ignoring routine maintenance can lead to expensive rehabilitation projects. The lesson learned for stormwater ponds is that "low maintenance" does not mean "no maintenance". Now that there are a number of successful alternatives to stormwater ponds, the pond maintenance lessons become even more important. Smaller BMPs will require a more frequent maintenance cycle, and native vegetation will require care to prevent invasion of non-native plant species.

The BMPs contained in this manual are recommended because each has been proven effective in the removal of pollutants from stormwater runoff. Long term effectiveness of all BMPs requires the regular removal of these accumulated pollutants to ensure capacity for ongoing pollutant removal. The *Stormwater Pond and Wetland Maintenance Guide* (CWP, 2004) describes a life cycle for ponds and wetlands that could apply to all structural BMPs.

Maintenance is necessary to prevent the following problems (CWP, 2004):

- Sediment accumulation, reduction in storage volume
- Debris blockage of structures
- Structural damage
- Invasive plants
- Loss of slope stabilization vegetation
- Reduced structural integrity of embankments, weirs or risers

This chapter includes detailed maintenance recommendations, check lists and cost information.

VII. Fact Sheets

These two-page fact sheets can act both as stand alone general education materials or as introductions to more detailed design guidance. Fact sheets present a general description of the BMP and overview information on suitability, key design considerations such as benefits and limitations, performance information, and site factors. For BMPs requiring more detailed design work, the fact sheets are supplemented with a narrative section providing more in depth guidance to the designer.

Fact sheets alone are provided for the following planning level BMPs and also in the case of Supplemental BMPs, where detailed design guidance is provided by the proprietor of these devices.

- Better Site Design
- Pollution Prevention
- Temporary Construction Sediment and Erosion Control
- Supplemental Best Management Practices

Supplemental guidance documentation, in addition to the stand alone fact sheets, is provided for the following BMPs:

- Green Roofs
- Rainwater Harvesting
- Pervious Surfaces
- Filtration
- Bioretention
- Infiltration
- Stormwater Ponds
- Stormwater Wetlands
- Soil Amendments

POLLUTION PREVENTION
RESIDENTIAL PRACTICES



Eagle Valley - Woodbury, MN

Definition:
Residential pollution prevention practices are household and neighborhood activities that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

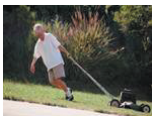
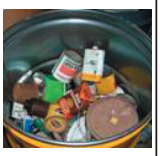
Description:
Residential pollution prevention practices prevent or reduce stormwater contamination from residential sources such as yards, driveways, sidewalks, and household products. These practices are often simple, low cost behavioral changes that improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Each of these practices are highly suitable and effective in cold climates. Table 8.1 indicates the pollutants controlled by various residential pollution prevention practices while Table 8.2 describes some of the methods used for each of these practices. See Photo Credits and References for further information.

Table 8.1 Residential Practices Pollutant Controls

Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Fertilizer and Pesticide Management	○	●	○	○	○	○	●
Litter and Animal Waste Control	○	●	○	●	●	○	○
Yard Waste Management	◑	●	○	◔	◔	○	○
Household Hazardous Waste Control	○	◔	●	○	○	●	●
Alternative Product Use	○	○	○	○	○	○	●
Better Car and Equipment Washing	◑	●	◑	○	○	◑	◑
Better Sidewalk and Driveway Cleaning	●	◑	◑	○	◑	◑	◔
Better Sidewalk and Driveway Deicing	◑	◔	◔	○	○	○	◑
Proper Pool Discharge	○	○	○	○	○	○	●
Septic Tank Maintenance	◔	●	○	●	○	○	◔
Exposed Soil Repair	●	◑	◔	◔	○	○	○
Native Landscaping	●	●	◔	◔	◔	○	○
Healthy Lawns	●	◑	◔	◔	○	○	○

Legend	
○ = Uncontrolled	◑ = Moderately Controlled
◔ = Slightly Controlled	● = Significantly Controlled

Source: modified from the Center for Watershed Protection

Table 8.2 Residential Pollution Prevention Methods		
Practice		Method
 [1]	Fertilizer and Pesticide Management	Reduce or eliminate the need for fertilizer and pesticides by practicing natural lawn care, planting native vegetation, and limiting chemical use; follow Minnesota Statutes Chapter 18C and federal regulatory requirements on fertilizer and pesticide storage and application if used.
 [1]	Litter and Animal Waste Control	Properly dispose of pet waste and litter in a timely manner and according to local ordinance requirements.
 [1]	Yard Waste Management	Prevent yard waste from entering storm sewer systems and water bodies by either composting or using curbside pickup services and avoiding accumulation of yard waste on impervious surfaces; keep grass clippings and leaves out of the street.
 [1]	Household Hazardous Waste (HHW) Control	Ensure that hazardous waste, including paints, stains, solvents, cleaning products, used motor oil, antifreeze, and pesticides, are disposed of properly by participating in a County household hazardous waste collection program; properly store hazardous waste items.
	Alternative Product Use	Use less harmful products including alternative cleaning solutions, pesticides, fertilizers, automotive and paint products to reduce the amount of toxic substances released into sewer systems.
 [1]	Better Car and Equipment Washing	Wash cars less often and on grassy areas using phosphorus-free detergents and non-toxic cleaning products or use commercial car washes to prevent dirty wash water from flowing to storm sewer systems and water bodies.
 [1]	Better Sidewalk and Driveway Cleaning	Sweep sidewalks and driveways and dispose of sweepings in the trash instead of using hoses or leaf blowers to clean surfaces.
 [1]	Better Sidewalk and Driveway Deicing	Reduce or eliminate the need for deicing products by manually clearing sidewalks and driveways prior to deicer use; use environmentally-friendly deicing products when possible, apply sparingly and store properly if used.
 [1]	Proper Pool Discharge	Check local ordinances for pool water discharge requirements; pool water should be discharged to sanitary sewer systems or held for a week or more without addition of chlorine prior to spreading over pervious areas to prevent stormwater contamination.
 [1]	Exposed Soil Repair	Use native vegetation or grass to cover and stabilize exposed soil on lawns to prevent sediment wash off.
	Native Landscaping	Reduce turf areas by planting native species to reduce and filter pollutant-laden runoff and prevent the spread of invasive, non-native plant species into the storm sewer system.
	Healthy Lawns	Maintain thick grass planted in organic-rich soil to a height of at least 3 inches to prevent soil erosion, filter stormwater contaminants, and absorb airborne pollutants; limit or eliminate chemical use and water and repair lawn as needed.

MUNICIPAL PRACTICES



Salt delivery to a Washington County Salt Shed

Definition:
Municipal pollution prevention practices are public operation and maintenance activities and educational efforts implemented by municipal staff that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

Description:
Municipal pollution prevention practices prevent or reduce stormwater contamination from public sources such as streets, parking areas, maintenance vehicles, storm and sanitary sewers, dumpsters, swimming pools and other potential stormwater hotspots. These practices improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Each of these practices is highly suitable and effective in cold climates. Table 8.3 indicates the pollutants controlled by various municipal pollution prevention practices while Table 8.4 describes some of the methods used for each of these practices. See Chapter 6 for further discussion of potential stormwater hotspots. See Photo Credits and References for further information.

Table 8.3 Municipal Practices Pollutant Controls

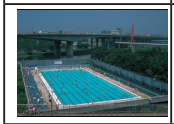
Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Temp. Construction Sediment Control	●	◑	◔	○	◔	○	○
Wind Erosion Control	●	◑	◔	○	◔	○	○
Streambank Stabilization	●	◑	○	○	○	○	○
Material Storage Control	●	◑	◑	○	○	●	●
Dumpster and Landfill Management	◔	◑	◑	●	●	◑	●
Proper Pool Discharge	○	○	○	○	○	○	●
Better Turf Management	◑	●	○	○	○	○	●
Better Street and Parking Lot Cleaning	●	◑	◑	○	◑	◑	◔
Better Street and Parking Lot Deicing	◑	◔	◔	○	○	○	●
Proper Vehicle Management	●	●	●	○	◑	●	●
Storm Sewer System Maintenance	●	◑	◔	○	◑	○	○
Sanitary Sewer System Maintenance	◔	●	○	●	○	○	◔
Litter and Animal Waste Control	○	●	○	●	●	○	○
Public Education	◑	◑	◑	◑	◑	◑	◑
Staff and Employee Education	◑	◑	◑	◑	◑	◑	◑

Legend

○ = Uncontrolled	◑ = Moderately Controlled
◔ = Slightly Controlled	● = Significantly Controlled

Source: Modified from the Center for Watershed Protection

Table 8.4 Municipal Pollution Prevention Methods

Practice		Method
	Temporary Construction Sediment Control	Implement and encourage practices to retain sediment within construction project area; see Temporary Construction Erosion and Sediment Control Factsheets for additional information.
	Wind Erosion Control	Institute a local program for wetting of open construction surfaces and other sources for windblown pollutants.
	Streambank Stabilization	Repair erosion occurring on a streambank of lakeshore in a timely manner; inspect bank areas for ice damage in the spring.
	Material Storage Control	Reduce or eliminate spill and leakage loss by properly inspecting, containing, and storing hazardous materials and having a cleanup plan that can be quickly and efficiently implemented.
	Dumpster and Landfill Management	Ensure that contaminated material is contained to prevent solid and/or liquid waste from being washed into storm sewer systems or water bodies.
	Proper Pool Discharge	Discharge pool water to sanitary sewer systems or hold for a week or more without the addition of chlorine prior to spreading over pervious areas instead of draining water directly to storm sewer systems. Follow local ordinances.
	Better Turf Management	Ensure that mowing, fertilization, pesticide application, and irrigation are completed in ways that will prevent or reduce grass clippings, sediment, and chemicals from entering storm sewer systems; use native vegetation where possible.
	Better Street and Parking Lot Cleaning	Maintain streets and parking lots frequently and especially in the spring by sweeping, picking up litter, and repairing deterioration; pressure wash pavement only as needed and avoid using cleaning agents.
	Better Street and Parking Lot Deicing	Properly store and conservatively apply salt, sand, or other deicing substances in order to prevent excessive and/or unnecessary contamination; implement anti-icing and prewet salt techniques for increased deicing efficiency.
	Proper Vehicle Management	Ensure that vehicles are fueled, maintained, washed and stored in a manner that prevents the release of harmful fluids, including oil, antifreeze, gasoline, battery acid, hydraulic and transmission fluids, and cleaning solutions.
	Storm Sewer System Maintenance	Regularly clean debris from storm sewer inlets, remove sediment from catch basin sumps, and remove any illicit connections to storm sewer systems.
	Litter and Animal Waste Control	Mandate litter and pet waste cleanup within the community and control waste-generating wildlife, such as geese; provide waste containers for litter and pet waste in public areas.
	Public Education	Label storm drains to indicate that no dumping is allowed and institute pollution prevention programs to educate and implement needed community practices.
	Staff, Employee, and Volunteer Education	Provide internal training for staff and provide direction to hired employees or volunteers regarding pollution prevention techniques to be used during work activities.

INDUSTRIAL & COMMERCIAL PRACTICES



Definition:
Industrial and commercial pollution prevention practices are private operation and maintenance activities implemented by owners or individuals responsible for industrial and commercial sites that prevent or reduce the contamination of stormwater.

KEY CONSIDERATIONS

Description:
Industrial and commercial pollution prevention practices prevent or reduce stormwater contamination from concentrated impervious surfaces and potential stormwater hotspots such as streets, parking areas, vehicles, smokestacks, and dumpsters. These practices improve subwatershed water quality by minimizing the introduction of pollutants including sediment, nutrients, metals, bacteria, trash, oil, and toxins. Table 8.5 indicates the pollutants controlled by various industrial and commercial pollution prevention practices while Table 8.6 describes some of the methods used for each of these practices. See Chapter 6 for further discussion of potential stormwater hotspots. See Photo Credits and References for further information.

Table 8.5 Industrial & Commercial Practices Pollutant Controls

Practice	Stormwater Pollutants Controlled						
	Sediment	Nutrients	Metals	Bacteria	Trash	Oil	Toxins
Temp. Construction Sediment Control	●	◑	◔	○	◔	○	○
Wind Erosion Control	●	◑	◔	○	◔	○	○
Emission Regulation	◔	○	●	○	●	○	●
Material Storage Control	●	◑	◑	○	○	●	●
Dumpster and Landfill Management	◔	◑	◑	●	●	◑	●
Better Turf Management	◑	●	○	○	○	○	●
Better Parking Lot Cleaning	●	◑	◑	○	◑	◑	◔
Better Impervious Surface Deicing	◑	◔	◔	○	○	○	●
Proper Vehicle Management	●	●	●	○	◑	●	●
Storm Sewer System Maintenance	●	◑	◔	○	◑	○	○
Sanitary Sewer System Maintenance	◔	●	○	●	○	○	◔

Legend

○ = Uncontrolled ◑ = Moderately Controlled

◔ = Slightly Controlled ● = Significantly Controlled

Source: Modified from the Center for Watershed Protection

Table 8.6 Industrial & Commercial Pollution Prevention Methods

Practice		Method
	Temporary Construction Sediment Control	Follow local, state, and federal regulatory requirements for control of erosion during construction activities.
	Wind Erosion Control	Institute a local program for wetting of open construction surfaces and other sources for windblown pollutants.
	Emission Regulation [1]	Follow local, state, and federal regulatory requirements for control of air emissions.
	Material Storage Control [1]	Reduce or eliminate spill and leakage loss by properly inspecting, containing, and storing hazardous materials and having a cleanup plan that can be quickly and efficiently implemented. Follow NPDES Industrial Permit requirements if permit authority applies.
	Dumpster and Landfill Management	Ensure that contaminated material is contained to prevent solid and/or liquid waste from being washed into storm sewer systems or water bodies.
	Better Turf Management [1]	Ensure that mowing, fertilization, pesticide application, and irrigation are completed in ways that will prevent or reduce grass clippings, sediment, and chemicals from entering storm sewer systems; use native vegetation where possible.
	Better Parking Lot Cleaning [1]	Maintain parking lots frequently and especially in the spring and fall by sweeping, picking up litter, and repairing deterioration; pressure wash pavement only as needed and minimize the use of cleaning agents.
	Better Impervious Surface Deicing [1]	Reduce or eliminate the need for deicing products by manually clearing sidewalks, driveways, and parking lots prior to deicer use; use environmentally-friendly deicing products when possible, apply sparingly and store properly if used.
	Proper Vehicle Management [1]	Ensure that vehicles are fueled, maintained, washed and stored in a manner that prevents the release of harmful fluids, including oil, antifreeze, gasoline, battery acid, hydraulic and transmission fluids, and cleaning solutions.
	Storm Sewer System Maintenance	Regularly clean debris from storm sewer inlets, remove sediment from catch basin sumps, and remove any illicit connections to storm sewer systems.
	Sanitary Sewer System Maintenance [2]	Regularly inspect and flush sanitary pipes to ensure that there are no leaks in the system and that the system is functioning properly.

Note: See page 7 for photo credits

Photo Credits

1. Courtesy of the Center for Watershed Protection
2. Courtesy of the Town of Amherst, New York
3. Courtesy of the United States Geological Survey

All other photos from EOR



VII. References & Photo Credits

Atlanta Regional Commission, 2001. Georgia Stormwater Management Manual.

Center for Watershed Protection (CWP). 1998. Better Site Design: a handbook for changing development rules in your community. US EPA. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection (CWP), 2004. Stormwater Pond and Wetland Maintenance Guidebook (draft). Prepared for Tetra Tech, Inc. and USEPA Office of Science and Technology.

City of Plymouth, 2005. Pond Maintenance Policy. Resolution No. 2005-102.

Northern Virginia Planning District Commission, Division of Environmental Services, 2000. Maintaining Your BMP, A Guidebook for Private Owners and Operators in Northern Virginia.

Toronto and Region Conservation Authority SWAMP Program. Storm Water Management Facility Sediment Maintenance Guide. Prepared by Greenland International Consulting Company.

Vermont Agency of Natural Resources, April, 2002. The Vermont Stormwater Manual.

Weiss, P.T., J.S. Gulliver and A.J. Erickson, 2005. The Cost and Effectiveness of Stormwater Management Practices: Final Report. University of Minnesota, St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota, 99p.

Web References

Atlanta Regional Commission. Georgia Stormwater Management Manual.
http://www.georgiastormwater.com/

California Stormwater Quality Association. Stormwater Best Management Practice Handbooks. http://www.cabmphandbooks.com

Center for Watershed Protection. Urban Subwatershed Restoration Manual, Manual 8: Pollution Source Control Practices. http://www.cwp.org/

REFERENCES

Center for Watershed Protection. Fact Sheets on Residential Pollution Prevention Practices
http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool8-Stewardship/residential.htm

Center for Watershed Protection. *Fact Sheets on Municipal Pollution Prevention Practices.*
http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool8-Stewardship/municipal.htm

Dakota County Environmental Education
http://www.co.dakota.mn.us/environ/education.htm

Government of Ontario, Canada. *Stormwater Pollution Prevention Handbook.*
http://www.ene.gov.on.ca/envision/water/stormwaterpph.htm

Hennepin County Environmental Education
http://www.co.hennepin.mn.us /vgn/portal/internet/hcchannelmaster/0,2324,1273_83263__2,00.html

Office of the Revisor of Statutes, State of Minnesota. *Minnesota Statutes 2004*.
http://www.revisor.leg.state.mn.us/stats/

University of Michigan Occupational Safety and Environmental Health. *Winter Maintenance: Snow and Ice Removal.*
http://www.oseh.umich.edu//salt.html

OVERVIEW



Math & Science Academy - infiltration trench
Woodbury, MN

KEY CONSIDERATIONS

Few watershed management practices simultaneously reduce pollutant loads, conserve natural areas, save money, and increase property values. Indeed, if such "wonder practices" were ever developed, they would certainly spread quickly across the nation. As it turns out, these practices have existed for years. Collectively called "better site design," the techniques employ a variety of methods to reduce total paved area, distribute and diffuse stormwater, and conserve natural habitats.

Better site design is a fundamentally different approach to residential and commercial development. It seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase natural lands set aside for conservation, and to use pervious areas for more effective stormwater treatment. To meet these goals, designers must scrutinize every aspect of a site plan— its streets, parking spaces, setbacks, lot sizes, driveways, and sidewalks— to determine if any of these elements can be reduced in scale. At the same time, creative grading and drainage techniques reduce stormwater runoff and encourage more infiltration.



Fields of St. Croix - stormwater finishing pond
Lake Elmo, MN

BETTER SITE DESIGN

Use the following outline as a guide to better site design (early on and throughout the design process) for development, redevelopment and retrofits. The first goal should be to minimize stormwater runoff. Mitigating any generated stormwater should be the second goal.

MINIMIZE STORMWATER RUNOFF

USE HYDROLOGY AS THE INTEGRATING FRAMEWORK

- Reproduce predevelopment hydrology
- Create a multifunctional landscape, which incorporates stormwater features into the landscape
- Use surface water elements as the focal point in civic spaces

PRESERVE AND EMULATE NATURAL DRAINAGE

- Utilize existing flow paths
- Fit development to the terrain
- Restore the drainage and/ or biological capacity of damaged or lost soils through mechanical improvements or soil amendments

SITE FINGERPRINTING

- Incorporate smaller lot sizes to minimize total impervious
- Confine construction and development to least critical / sensitive areas
- Preserve open space / natural areas
- Reduce limits of clearing and grading
- Stage construction (limit area exposure of the site at any one time)
- Minimize soil compaction

IMPERVIOUS SURFACES

- Reduce
- Minimize
- Disconnect

MITIGATE STORMWATER RUNOFF

THINK MICROMANAGEMENT

- Control runoff at the source
- Minimize runoff by maximizing infiltration, evapotranspiration, and filtration
- Employ natural processes for water quality improvement

STORMWATER TREATMENT TRAIN

- Utilize simplistic, non-structural methods
- Use redundant runoff treatment systems
- Highly suitable for cold climates

BETTER SITE DESIGN

RESIDENTIAL STREETS & PARKING LOTS

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The key objective is to provide planners, developers, and local officials with benchmarks to investigate where existing ordinances may be modified to reduce impervious cover, conserve natural areas, and prevent stormwater pollution. The City of Inver Grove Heights identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.



EXAMPLES

Fields of St. Croix - Lake Elmo, MN

This residential conservation development uses minimum road widths and landscaped areas to reduce the amount of impervious surfaces and add to the rural character of the neighborhood. Vegetated channels and bioretention areas are used in the right-of-way to treat stormwater runoff.



H.B. Fuller - Vadnais Heights, MN

This parking lot incorporates bioretention strategies to treat stormwater runoff. The landscaped depressions provide stormwater treatment, snow storage, and improved parking lot aesthetics and climate. Low maintenance sedges are used in place of traditional turf grass to lower maintenance costs and pollution.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for street and parking lot development, redevelopment and retrofits. Place a check in the appropriate boxes if you think that this approach will work for your site.

RESIDENTIAL STREETS AND PARKING LOTS CHECKLIST

☑	Design residential streets for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency, maintenance, and service vehicle access. For public streets install 28 foot paved width streets with a sidewalk/trail on one side (24 foot for private streets)
☑	Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce impervious cover. The radius of cul-de-sacs should be 35 feet. Consider alternative turnarounds.
☐	Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located outside of the BMPs section of the right-of-way wherever feasible.
☐	Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
☐	Where density, topography, soils, and slope allow, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.
☐	Enforce the required parking ratio governing a particular land use or activity as both a maximum and a minimum, in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance, taking into account local and national experience to determine if lower ratios are warranted and feasible.
☐	Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, making use of vegetated parking islands, and using pervious materials in spillover parking areas where possible.
☐	Provide stormwater treatment, wherever possible, for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The City of Inver Grove Heights has identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.



EXAMPLES

Jackson Meadow - Marine on St. Croix, MN

Flexible design standards promote open space design development. Design standards encourage reductions of overall imperviousness, smaller lot sizes, preservation of natural areas, community open space, watershed protection, and unique neighborhood identity.



Lilydale - Inver Grove Heights, MN

Shared driveways in a development can significantly reduce the amount of overall imperviousness.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for street and parking lot development, redevelopment and retrofits. Place a check in the appropriate boxes if you think that this approach will work for your site.

LOT DEVELOPMENT CHECKLIST

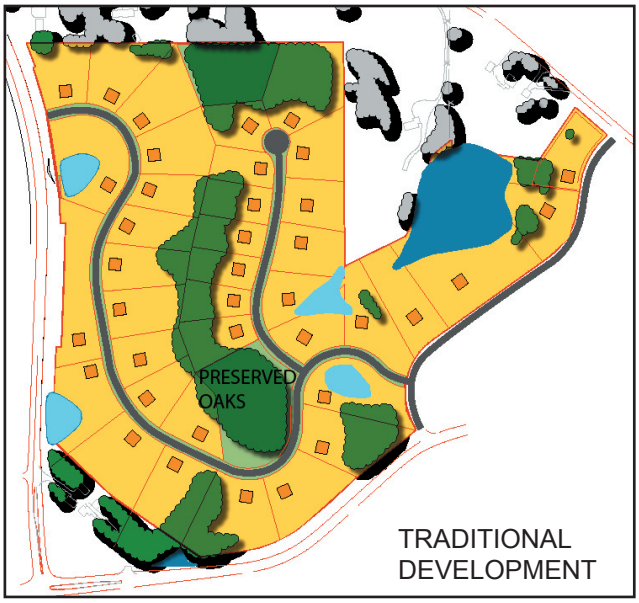
☑	Reduce overall lot imperviousness by installing alternative driveway surfaces, shorter or narrower (<20 feet) driveways, and shared driveways that access two or more homes.
☐	Clearly specify how community open space will be managed, and designate a sustainable legal entity responsible for managing both natural and recreational open space.
☐	Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.
☐	Restore the drainage and/ or biological capacity of damaged or lost soils through mechanical improvements or soil amendments.
☐	Consider joint parking arrangements or other methods (underground parking, tuckunder parking, etc.) for reducing the size of parking lots.
☐	Where possible incorporate pervious surfaces for parking surfaces, turn arounds, patios, sidewalks and/or driveways.
☐	Consider open space design development incorporating smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

CONSERVATION OF NATURAL AREAS

KEY CONSIDERATIONS

Model development principles provide design guidance for economically viable, yet environmentally sensitive development. The City of Inver Grove Heights has identified areas where existing codes and standards could be changed to better protect streams, lakes and wetlands in the Northwest Area and incorporated those changes into the PUD. These principles are also highly suitable and effective in cold climates.

Each principle is presented as a simplified design objective. Actual techniques for achieving the principle should be based on local conditions. Please consult Chapter 4 for more detailed information on better site design.





COMPARISON

Traditional Residential Developments vs. Conservation Design Developments

Flexible design standards can allow for the conservation of a site's natural areas and ecological function. Conservation design developments advocate preserving a site's most distinguishing natural features and integrating them into the community of the new development. Open space should be consolidated to have the greatest recreational, aesthetic, and environmental benefit.

Smaller lot sizes allow the same densities as a traditional development, with more open space dedicated as a community amenity. Flexible lot design allows less roads and stormwater infrastructure to be built, reducing imperviousness and infrastructure costs.

BETTER SITE DESIGN

Use the following checklist as a tool to better site design (early on and throughout the design process) for development, redevelopment and retrofits. Place a check in the appropriate boxes if you think this approach will work in your site.

CONSERVATION OF NATURAL AREAS CHECKLIST

☑	Preserve at least 20% of the net developable areas within the PUD as additional natural area/open space. This may include greenways as shown in the Inver Grove Heights Natural Resources Inventory and Management Plan.
☑	Open space design or cluster development is promoted as a means of conserving natural areas by allowing an increased mixture of housing types for each zoning district.
☑	Wetland management standards assign slope-dependent buffer width to each wetland management classification
☐	Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas.
☐	Prevent the discharge of unmanaged stormwater from new stormwater outfalls into wetlands, sole-source aquifers, or ecologically sensitive areas.
☐	Preserve or restore riparian wetland buffers with native vegetation. Maintain the buffer system through the plan review delineation, construction, and post-development stages.
☐	Limit clearing and grading of forests and native vegetation at a site to the minimum area needed to build lots, allow access, and provide fire protection. Manage a fixed portion of any community open space as protected green space in a consolidated manner.

TEMPORARY CONSTRUCTION EROSION AND SEDIMENT CONTROL



Site without temporary sediment control



Site with temporary sediment control

Definition:

Temporary construction erosion and sediment control is the practice of preventing or reducing the movement of sediment from a site during construction through the implementation of man-made structures, land management techniques, or natural processes. Note that this Fact Sheet does not contain detail on the use of specific BMPs. Because there are many good resources on erosion and sediment control, this Fact Sheet merely discusses their use and refers the reader to other useful resources for detail.

DESCRIPTION

Temporary construction erosion and sediment control limits the amount of sediment that is carried into lakes, wetlands, and infiltration facilities by storm water runoff. Sediment can clog the bottom of infiltration practices and also carries nutrients and pollutants that degrade water resources and harm aquatic wildlife. Proper planning of construction site activities greatly reduces the impact of soil disturbance activities on nearby resources and diminishes the need for costly restorations. A construction plan that limits sediment disturbance in potential problem areas and uses effective temporary sediment control practices will lessen negative impacts to local water resources and infiltration practices.



To establish a construction plan that will minimize sediment movement, designers will need information on existing site conditions and neighboring resources that require special consideration including water bodies, natural areas, bluffs and other highly erodible or sensitive areas. Construction activities should be designed in a manner that minimizes overall soil disturbance and phases areas of disturbance such that the amount of land disturbed at any one time is reduced. This type of planning will limit the need for larger structural sediment control solutions. Additionally, the designer should determine which local, state, and federal agencies require permits for the type of work planned. The site plan will need to account for the requirements of all agencies issuing permits.

In a closed basin system like the Northwest Area, infiltration is a major component of the stormwater management strategy. Temporary construction erosion and sediment control is critical for protecting these sensitive infiltration areas from clogging and ensuring that they function properly. Inver Grove Heights city code requires that a site construction plan, including details of the temporary construction erosion and sediment control practices, be submitted with the Storm Water Management Plan.



Photo: MPCA

The practices included in the site construction plan and SWPPP (if one is required for the project by state law) will need to control runoff, stabilize slopes and exposed soils, and limit the movement of soils into infiltration practices, receiving waters, and natural areas. A key factor in accomplishing these goals is the sequencing of construction activities such that the minimum possible area is disturbed at any one time. Initial site work should include establishing protective buffer zones adjacent to onsite resources, including infiltration areas, that require protection and setting up perimeter sediment controls. During the course of construction, a variety of erosion prevention and sediment control practices may be necessary in order to stabilize slopes and drainageways, protect inlets to the storm water conveyance system, protect infiltration practices, limit gully formation, and capture sediment. Table 8.7 summarizes some of the most common temporary erosion and sediment control practices, the on-site areas to use the practices, and the method of use for each of the practices. Table 8.8 indicates requirements and the temporary sediment control practices that can be used to fulfill these requirements. Temporary seeding is not erosion protection or sediment control until vegetation is established or until the area is protected with an erosion control blanket. Projects that are actively under construction in winter/ frozen months should include additional inspection and clean-up activities. Temporary sediment basins should be sized to include extra storage for snowmelt, as discussed in Chapter 6. Temporary sediment basins should not be located in areas that will be used for infiltration practices once construction is complete.

A final key element to ensure effectiveness of the erosion and sediment control plan is the implementation of an inspection and maintenance program. Frequent inspection and maintenance activities ensure that the installed temporary sediment control practices are operating effectively throughout the course of the project.

References

Minnesota Department of Transportation, 2003. *2003 Seeding Manual*. http://www.dot.state.mn.us/environment/pdf_files/SeedingManual2003.pdf

Minnesota Department of Transportation, 2000. *Mn/DOT Standard Specifications for Construction*. http://www.dot.state.mn.us/tecsup/spec/

Minnesota Erosion Control Association and Minnesota Department of Transportation, 2001. *Erosion & Sediment Control Certification & ETeam Training Program 2001*. http://www.dot.state.mn.us/environment/pdf_files/TrnManCl.pdf

Minnesota Local Road Research Board, Federal Highway Administration, and Minnesota Department of Transportation, 2003. *Erosion Control Handbook for Local Roads*. Manual Number 2003-08. http://www.lrrb.gen.mn.us/pdf/200308.pdf

Minnesota Pollution Control Agency, 2005. ***NPDES General Permit for Storm Water Discharges From Construction Activities.*** http://www.epa.gov/npdes/pubs/cgp2003_entirepermit.pdf

Minnesota Pollution Control Agency, 2000. *Protecting Water Quality in Urban Areas*.
http://www.pca.state.mn.us/water/pubs/sw-bmpmanual.html

Minnesota Pollution Control Agency, 2004. *Storm water Compliance Assistance Toolkit for Small Construction Operators*.
http://www.pca.state.mn.us/publications/wq-strm2-09.pdf

Table 8.7 Temporary Sediment Control Practices

Temporary Sediment Control Practice		Erosion Protection	Sediment Control	Areas to Use				Method
				Perimeter	Slopes	Drainage-ways	Other	
	Vegetated Buffers Photo: MPCA	X		X	X	X	Around Trees, Water Bodies, Natural Areas	Vegetated buffers are areas designated to remain undisturbed in order to protect lakes, wetlands, infiltration zones or natural areas. Buffers should be marked and maintained around all resources requiring protection.
	Silt Fence		X	X	X	X	Drainage System Inlets, Infiltration Areas	Silt fence filters sediment from runoff by allowing water to pass through a geotextile fabric or by creating a pool to allow sediment to drop out of the water column. Silt fence is installed primarily at downslope boundaries of the work area but can also be used for inlet protection, identification of infiltration areas and around the perimeter of stockpiles.
	Fiber Log		X	X	X	X	Drainage System Inlets	Fiber logs include straw, wood, or coconut fiber logs, compost logs, and rock logs that slow water and filter sediment. Fiber logs are used for inlet protection, ditch checks, and as perimeter control where silt fence is infeasible.
	Rock Construction Entrance		X	X				A rock construction entrance is a bed of rocks that helps to remove sediment from vehicle tires. Rock construction entrances should be placed at all site access points. The use of 1 1/2 inch - 3 inch clear aggregate is recommended. Periodic cleaning or replacement is recommended.
	Grade Breaks		X		X			Grade breaks are changes in slope that break up concentrated flow, preventing the formation of gullies. Grade breaks should be incorporated into long slopes.
	Temporary Seeding	X	X		X	X		Temporary seeding allows plants to stabilize the soil through vegetation and root growth. A large variety of plants are available for temporary seeding of different conditions; the most common are rye grass, winter wheat, and oats.
	Erosion Control Blanket	X	X		X	X		Erosion control blanket is a mat made of netting layered with straw, wood, coconut or man-made fibers that prevents erosion by sheltering the soil from rainfall and runoff while holding moisture for establishing plants. Blankets are installed in channels or on slopes where mulch would not be adequate.

Table 8.7 Temporary Sediment Control Practices

Temporary Sediment Control Practice		Erosion Protection	Sediment Control	Areas to Use: Perimeter	Areas to Use: Slopes	Areas to Use: Drainageways	Areas to Use: Other	Method
	Mulch	X			X			Mulch is wood fibers, compost, wood chips, straw, or hay that is applied as a cover to disturbed soil. Mulch reduces erosion by absorbing energy from rainfall and runoff and provides protection and moisture for the establishment of vegetation, when properly disc anchored or spread.
	Hydraulic Mulch	X			X			Hydraulic mulches for erosion control are typically comprised of wood fibers and are applied by hydroseeding equipment. Hydraulic mulches are typically used in areas with steeper slopes or where equipment access would be difficult.
	Temporary Pipe Downdrains	X			X			A temporary pipe downdrain conveys runoff down slopes in a pipe so that runoff will not cause erosion. Pipe downdrains are installed where concentrated flow would drain onto a disturbed slope.
	Flotation Silt Curtain		X				Lakes, Wetlands, Streams	Flotation silt curtain is fabric fence installed in water bodies to contain sediment near the banks of the work area. Must be used in conjunction with other sediment control techniques
	Rock or Compost Bags		X		X	X	Drainage System Inlets	Rock and compost bags are filled bags that are used to filter water, control ditch grade, or to provide inlet protection.
	Rock Check Dam		X			X		Rock check dams are rocks piled across a ditch to slow flows and capture sediment. Rock checks are installed perpendicular to flow and should be wide enough to ensure that flow remains in the center.
	Riprap	X				X	Drainage System Outlets	Riprap is appropriately sized rocks that reduce the energy of fast moving flows. Riprap is used along channels and at outfalls.
	Temporary Sedimentation Basin		X				Throughout Site	Temporary sedimentation basins are depressions that capture runoff to slow the flow of water and allow sediment to settle out.
	Filter Bag Photo: Dandy Corp.		X				Drainage System Inlets	Filter bags are mesh bags that capture sediment but allow water to pass through. Filter bags are installed in storm drain inlets.

Table 8.8 NPDES and Inver Grove Heights Requirements and Associated Erosion Protection and Sediment Control Practices

NPDES General Construction Storm water Permit Requirement * *specific requirements may vary as specified in General Permit Appendix A	Temporary Erosion Protection and/or Sediment Control Practice														
	Vegetated Buffers	Silt Fence	Fiber Log	Rock Construction Entrance	Grade Breaks	Temporary Seeding	Erosion Control Blanket	Mulch	Hydraulic Mulch	Temporary Pipe Downdrains	Flotation Silt Curtain	Rockbags/Sandbags/ Compostbags	Rock Check Dam	Riprap	Sedimentation Basin	Filter Bag
Delineate areas of no disturbance before beginning site work.	X															
Sediment control must be established on all down gradient perimeters prior to commencement of land disturbing activities.		X	X								X					
Vehicle tracking of sediment must be minimized.				X												
All storm drain inlets must be protected.		X	X									X				X
Install energy dissipation measures at pipe outlets within 24 hours of connecting to a surface water.														X		
Drainage ditches within 200 feet of a surface water or the property edge must be stabilized within 24 hours of connection to a surface water.			X			X	X	X*	X*				X	X		
No unbroken slope of length greater than 75 feet for slopes of 3:1 or steeper.																
Slopes within 200 feet of a surface water must have temporary protection or permanent cover within the following time frame based on slope: **Slope** — **Time** Steeper than 3:1 — 7 days 10:1 to 3:1 — 14 days Flatter than 10:1 — 21 days			X		X	X	X	X	X	X						
Install temporary basin where 10 acres or more drains to a common location.															X	
Infiltration / open space areas shall be staked off during construction to restrict heavy equipment traffic from compacting native soils and/or prevent these areas from becoming staging areas																

Table 8.8 NPDES and Inver Grove Heights Requirements and Associated Erosion Protection and Sediment Control Practices																
NPDES General Construction Storm water Permit Requirement * *specific requirements may vary as specified in General Permit Appendix A	**Temporary Erosion Protection and/or Sediment Control Practice**															
	Vegetated Buffers	Silt Fence	Fiber Log	Rock Construction Entrance	Grade Breaks	Temporary Seeding	Erosion Control Blanket	Mulch	Hydraulic Mulch	Temporary Pipe Downdrains	Flotation Silt Curtain	Rockbags/Sandbags/ Compostbags	Rock Check Dam	Riprap	Sedimentation Basin	Filter Bag
If the stormwater BMP is being designed to serve as a temporary sediment basin, grade the BMP to within three (3) feet of final grade to protect the underlying material from clogging. Once construction in the contributing drainage area has been completed and the site is stabilized, excavate the infiltration practice to final grade and complete construction of the BMP																

Source: Modified from the Minnesota Stormwater Manual

VI. Guidance Documents

Guidance documents have been developed for those best management practices that provide a reduction in the volume of stormwater runoff leaving the site. Guidance documents contain more in depth design information and considerations than could be contained in a fact sheet alone. The order these guidance documents are presented reflects the order they would be used if applying a treatment train approach to stormwater management. Guidance documents have been developed for the following BMPs.

- Green Roofs
- Rainwater Harvesting
- Pervious Surfaces
- Filtration
- Bioretention
- Infiltration
- Stormwater Ponds
- Stormwater Wetlands
- Soil Amendments

GREEN ROOFS



Courtesy of The Green Institute - Minneapolis, MN

Definition:
Green roofs consist of a series of layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention.

KEY CONSIDERATIONS

Design Criteria:

- Structural load capacity, how much weight the roof can hold, is a major factor in determining whether the green roof is "extensive" or "intensive" (see next page).
- Vegetation selection is based on numerous factors including, growth medium depth, microclimate, irrigation availability and maintenance.
- A leak detection system is recommended to quickly detect and locate leaks.
- Modular products can increase installation and repair efficiency.

Benefits:

- Reduce, delay, and cool stormwater runoff.
- Insulate buildings and lower energy consumption and costs.
- Provide habitat for birds and insects.
- Increase longevity of traditional roofing systems by protecting from ultraviolet rays.
- Reduce carbon dioxide levels and heat island effect.

Limitations:

- Cost is higher than traditional roofing systems – can be significant for retrofits.
- Leaks can cause significant damage and can be hard to locate and repair without an electronic leak detection system.
- Conditions can be harsh for vegetation establishment.
- Maintenance needs can be higher than traditional roofing system.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration *with appropriate soil & conditions
X	Screening/ Filtration
X	Temperature Control
	Settling
X	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA	Total Suspended Solids
NA	Nutrients - Total Phosphorus/ Total Nitrogen
NA	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbons, Pesticides

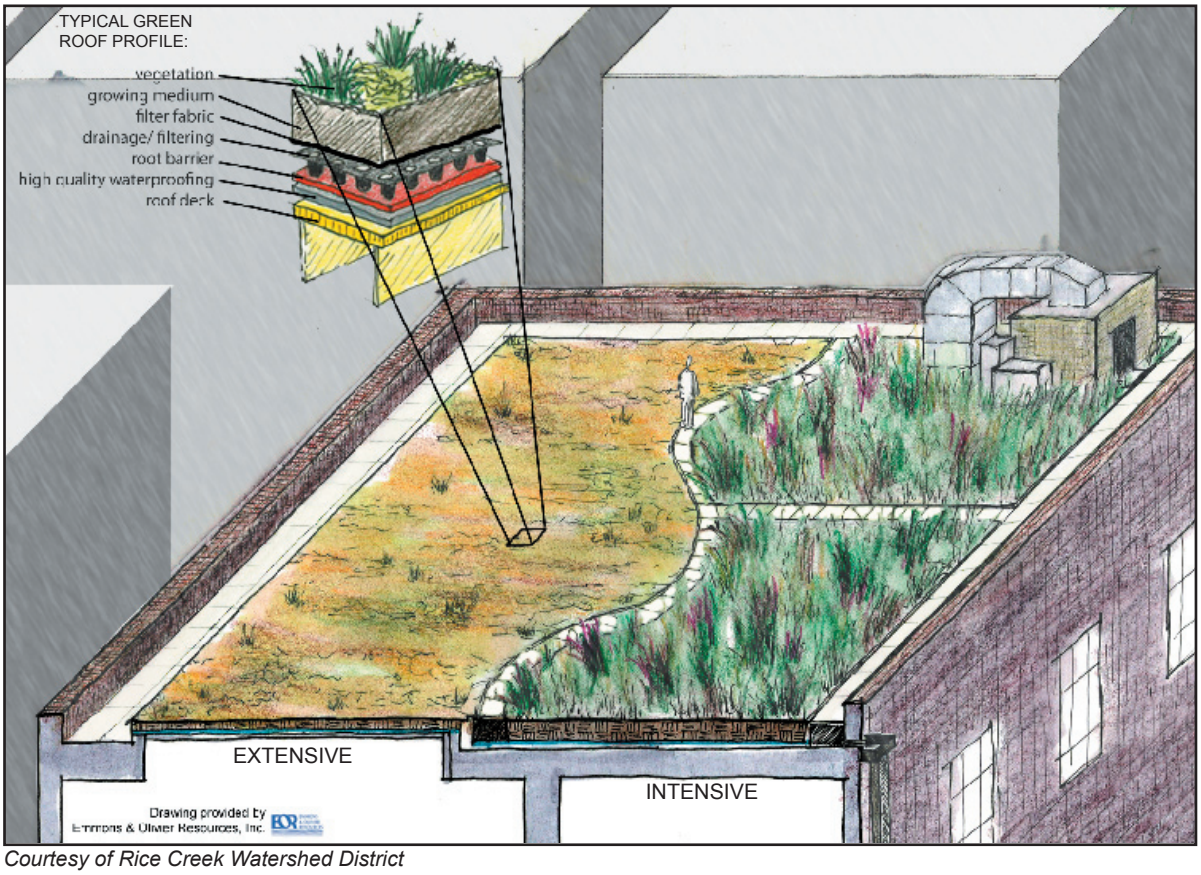
Note: Pollution removal percentages apply to volume of runoff treated, and not to volume by-passed

SITE FACTORS

Rooftop	Drainage Area
30%	Max. Slope *additional slippage control used for slopes >30%
NA	Min. Depth to Bedrock
NA	Min. Depth to Water Table
NA	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Good	Freeze/ Thaw Suitability
NA	Potential Hotspot Runoff *requires impermeable liner

Description:
There are two systems of green roofs, extensive and intensive, composed of the same system of layers. Extensive systems are lighter, typically have 4 inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses (such as maintenance personnel). Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic.

Rainfall is initially intercepted by vegetation, held on foliage, or soaked up by plant roots. Any remaining runoff filters through the growing medium and is drained away from the roof's surface by the drainage layer. Some drainage systems use small depressions to store excess water for uptake during drier conditions (RCWD 2005), while others provide an overflow for larger rainfall events.



Courtesy of Rice Creek Watershed District

A. Suitability

General

Green roofs consist of a series of layers that create an environment suitable for plant growth without damaging the underlying roof system. Green roofs create green space for public benefit, energy efficiency, and stormwater retention/ detention. Design variants include; extensive use and intensive use green roofs. Rainfall is initially intercepted by vegetation, held on foliage, or soaked up by plant roots. Any remaining runoff filters through the growing medium and is drained away from the roof's surface by the drainage layer. Some drainage systems use small depressions to store excess water for uptake during drier conditions (RCWD 2005), while others provide an overflow for larger rainfall events.

Function Within Stormwater Treatment Train

Green roofs are the first step in the treatment train. They can be designed to provide stormwater reduction, detention and cooling. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- ► reduce stormwater pollutants (through reduced total runoff)
- ► decrease runoff peak flow rates
- ► decrease the volume of stormwater runoff
- ► reduce thermal impacts of runoff.

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Green roofs should be designed for volume control. Storage should be provided so that rainfall is collected and stored before evaporating or transpiring back to the atmosphere. Volume reduction may be applied to the 5-year 24-hour standard for any storage provided below the roof overflow elevation. Additionally, volume credit may be allowed above the roof overflow but the amount of volume credit will be based on substrate properties and will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

There are two types of green roofs, extensive and intensive, composed of the same system of layers. Buildings may have a combination of extensive and intensive areas on the same roof.

Extensive Use Green Roof – Extensive systems are lighter, typically have 4 inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses (such as maintenance personnel).

Intensive Use Green Roof – Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic and recreational use. In reality, there are varying degrees of intensive green roofs, ranging from fully intensive uses such as miniature golf to semi-intensive uses that integrate walking paths and passive recreation.

Retrofit Suitability

Green roof retrofits are possible depending on the structural support offered by the existing building. An engineer experienced in green roof retrofits should be used to assure that the structure is suitable. Green roofs are highly desirable as retrofit practices in watersheds that are concerned about water temperature, runoff volume and runoff rates.

Cold Climate Suitability

Care must be taken to ensure that plants are correctly selected for green roofs. They must be hardy and winter tolerant. Using native plants increases the likelihood of plant survival. Some green roofs may be able to house evergreens, creating a year-round green roof. See the planting guide in Appendix B for species that will work well in Inver Grove Heights.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the green roof configuration. Green roofs reduce volume through rainfall interception on plant surfaces, evaporation or transpiration. Green roofs can also be designed to have depressional storage incorporated into the landscape, increasing the holding capacity of the roof and providing water for plants during dry periods.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirements when green roofs are used. However, these practices can help reduce retention requirements for a site through volume reduction. Larger green roofs have the potential to provide greater water quantity benefits due to their size.

Water Quality Treatment

Monitoring data on green roof runoff is limited but a Swiss study (Berdtsson-Bengtsson, 2005), indicates that green roofs act as a source for phosphorus and a sink for nitrogen. Surcharge storage above the green roof outlet is available for detention. Utilizing this detention can lower peak discharges from the roof. Outlet structures can be sized to partially or fully accommodate larger storm peak discharge control while allowing the volume below the outlet to be used by the vegetation at a later time. This detention can decrease peak flows in downstream waterways.

Green roofs can also remove atmospheric pollutants through filtration, soil adsorption, and biological uptake. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Because green roofs do not get as hot in the summer, the runoff leaving a green roof can be expected to be cooler then the runoff leaving a conventional roof. A pollutant removal table is not provided due to the variability of green roofs and the limited monitoring data available.

Limitations

The following general limitations should be recognized when considering installation of a green roof:

- ► Limited monitoring data are available
- ► Failure can occur due to improper siting, design, construction and maintenance
- ► Cost is higher than traditional roofing ($14-$25 /ft^2, Greenroofs.com)
- ► Leaks can be hard to locate and repair without an electronic leak detection system
- ► Conditions can be harsh for vegetation establishment
- ► Maintenance needs can be higher than traditional roofing system

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use green roofs for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgement as to whether or not a green roof is the appropriate BMP for the site.

- ► Structural support – The structure should be able to support the additional weight of a green roof. An extensive green roof is relatively lightweight and generally within the normal load-bearing capacity of modern roof structures. Intensive green roofs vary greatly in weight but will need to be considered in structural design. A structural engineer must certify the existing or proposed structure.
- ► Accessibility – The green roof should not obstruct maintenance personnel and should be built only on roofing surfaces, not on mechanical components.
- ► Soils – It is HIGHLY RECOMMENDED that engineered soils be used. Engineered soils are lighter and have consistent characteristics desirable for roofing. Under the supervision of a structural engineer and/or landscape architect, topsoil can be used or incorporated into the engineered soil.

Conveyance

The first part of stormwater is received on plant surfaces. Once the initial abstractions from plant surfaces are saturated, green roof conveyance starts by infiltrating stormwater through the growing media. Stormwater is then conveyed through a drainage media (porous or granular material) to a drain at the edge of the roof. Water that is not retained within the plant surfaces, soil media or drainage media is conveyed to further stormwater systems via a downspout.

Pretreatment

- ► Green roofs require no pretreatment but can act as a pretreatment practice for small impervious areas on the roof. (HVAC systems, walkways, etc.)

Treatment

The following guidelines are applicable to the actual treatment area of a green roof.

- ► Space Occupied – Generally the entire rooftop, but partial rooftop installations are possible
- ► Practice Slope – Slope of roof. The practical maximum slope of a green roof is 30 percent. It is possible to create green roofs on steeper slopes but additional slippage control may need to be used.
- ► Depth – The soil depth of a green roof can range from 3” in extensive green roofs to 18” for intensive green roofs. The depth is dependent on the type of vegetation to be planted and the intent of use.
- ► Aesthetics – Green roofs can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. Generally, all green roofs serve environmental and economical benefits while providing an aesthetic amenity.

Landscaping

- ► It is REQUIRED that the roof be established with dense and healthy vegetation as soon as possible after the growing medium is deposited.
- ► It is HIGHLY RECOMMENDED that vegetation on green roofs be regularly maintained and bare areas seeded.
- ► It is HIGHLY RECOMMENDED that green roofs are provided an irrigation system. Regular watering is REQUIRED during the establishment of vegetation. Using a rainwater harvesting system is a common way to provide irrigation water for a green roof.

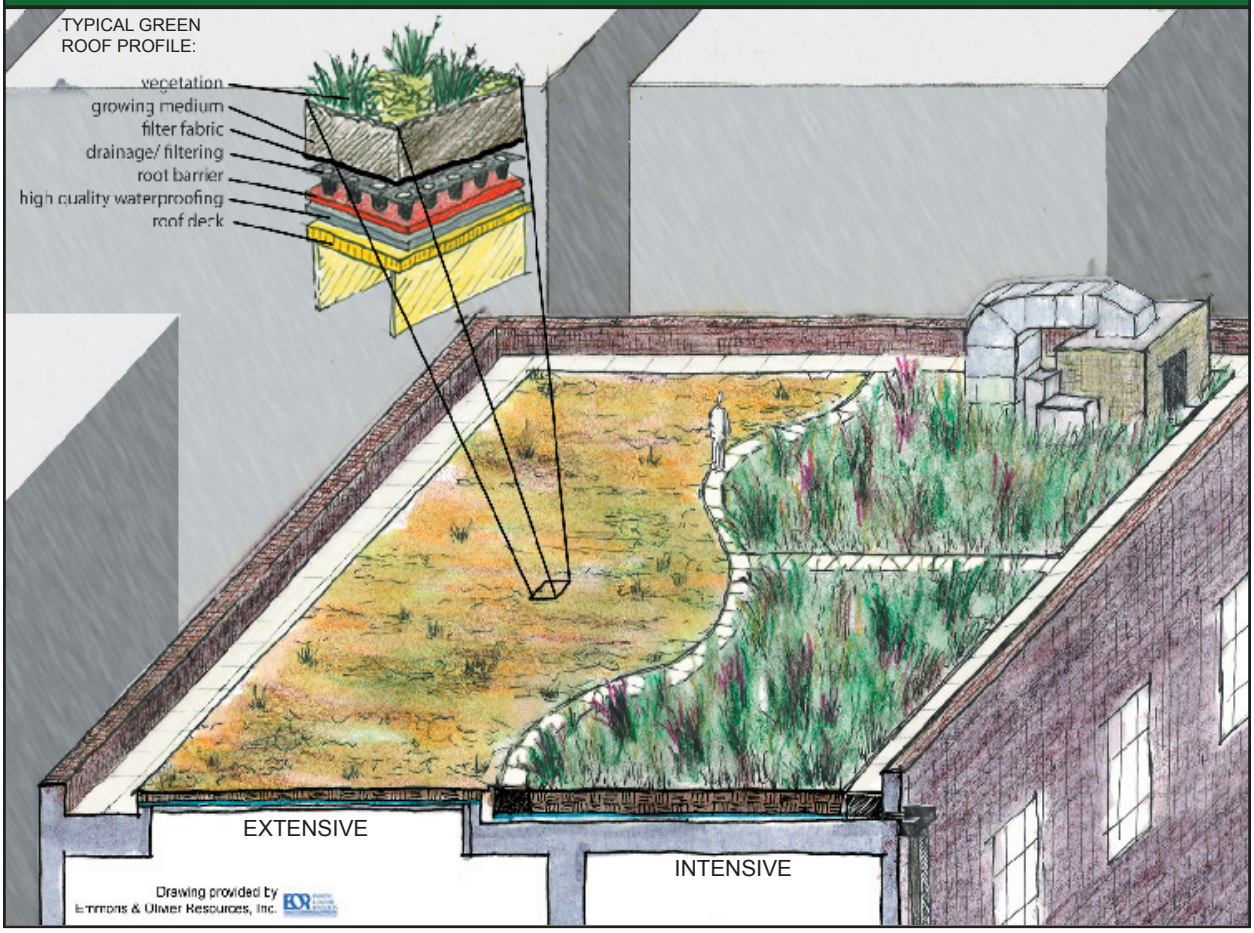
Safety

- ► Many roof safety measures that apply to conventional roofing also apply to green roofs.
- ► OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for construction sites: http://www.osha.gov/pls/oshaweb/

C. Construction Details

Because of the proprietary nature of green roofs, no construction details are provided. Rather, the components of a typical green roof are shown in Figure 8.2.

Figure 8.2 Typical Intensive and Extensive Green Roofs



Courtesy of Rice Creek Watershed District

D. Construction Specifications

Construction of green roofs incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that an engineer experienced in green roof construction be contracted for the final design plans and specifications. Table 8.9 identifies a majority of the green roof components, function, and level of necessity.

I. Temporary Erosion Control
- ► Installation prior to site disturbance
- ► Catch basin/inlet protection
- ► Secure media with erosion control mat

II. Equipment, Transportation, and Components
- ► Timing of green roof construction (relative to total site development)
- ► Use of light weight equipment suitable for rooftop work
- ► Conveyor, elevator or blower to transport media to the roof
- ► Restoration in the event of disturbance during construction of practice
- ► Underdrain specifications
- ► Waterproofing specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix B of the Manual, ASTM Green Roof Standard 2400)
- ► Site preparation of planting areas
- ► Timing of native seeding and native planting
- ► Watering of plant material
- ► Weed control

IV. Construction Sequence Scheduling
- ► Priming deck
- ► Insulation
- ► Waterproofing Layer
- ► Leak Test
- ► Filter fabric
- ► Irrigation system
- ► Growing Medium
- ► Seed and Plant
- ► Installation of semi-permanent and permanent erosion control measures

V. Construction Observation
- ► Adherence to construction documents
- ► Continual site management
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately
- ► Completion of Construction

Table 8.9 Green Roof Components

Component	Function	Description	Necessity
High quality waterproofing	Prevents water from entering the building	Impervious concrete, liquid membranes, 1-ply sheets, multiple layers	Required
Root repellent system	Prevents unwanted plants from compromising the waterproofing	Metal, poured concrete	Required
Drainage and filtering	Drains growth media to prevent drowning	Porous mats, granular media, polystyrene, coconut mats, plastics	Required
Growing medium	Plant survival, stormwater retention, habitat	Engineered soils with a mixture of organic and inorganic matter	Required
Vegetation	Aesthetics, insulations, stormwater management	Perennials, biennials or annuals, non-aggressive roots	Required
Insulation	Energy savings, protect plant roots	Vegetable fiber, glass fiber, polystyrene foam, other foams	Recommended
Membrane protection cloth	Protect membranes from construction stress	Polyester fiber mats, non-woven landscape fabric	Recommended
Leak detection system	Ensure waterproofing, easily locate leaks	Electronic Field Vector Mapping is an electronic leak detection system	Recommended
Ponds and pools	Aesthetics, stormwater management	Waterfalls, fountains, ponds	Optional
Irrigation system	Ensures plant survival	Overhead, surface drip, capillary, base drip, or trickle	Optional
Walkways	Accessibility, pedestrian flow control	Numerous types of walkways are suitable	Optional
Curbs and borders	Aesthetics	Numerous types of curbs and borders are suitable	Optional
Railings	Protect people from falls, Aesthetics, limit access	Numerous types of railings are suitable	Optional
Lighting	Aesthetics, night time use, security	Numerous types of lighting is suitable	Optional

Source: Adapted from GRHC 2004

E. Operation and Maintenance

Overview

Effective long-term performance of green roofs requires a green roof management plan (HIGHLY RECOMMENDED), performance monitoring (HIGHLY RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The green roof management plan (operation plan) should address the following items: vegetation management (feeding, plant protection, drainage and weeding), wet/dry cycling of soils, and dewatering procedure. The monitoring plan should address the following items: inspection and efficiency assessment, water quality and quantity monitoring of runoff leaving the roof, and plant tolerances.

Construction and Maintenance Costs

Table 8.10 is a list of the general components used in construction of this practice. Utilizing Table 8.10 will allow designers to avoid over or under estimation of fixed costs.

Table 8.10 Green Roof Cost Components

Implementation Stage	Primary Cost Components	Basic Cost Estimate
Structural Components	Electronic Leak Detection System	($/square yard)
	Outflow components	($/structure)
	High Quality Waterproofing	($/square yard)
	Root Barrier	($/square yard)
	Drainage/Filtering Media	($/square yard)
	Filter Fabric	($/square yard)
	Growing Media	($/cubic yard)
	Vegetation	($/square yard of seed and mulch) or ($/plant)
	Overflow weir/baffle	($/structure)
Annual Operation, Maintenance, and Inspection	Weeding	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Watering	($/gallon)
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)
	Mowing (for some green roofs)	Mowing Cost ($) x Mowing Frequency (6x / 1 yr)

F. Design Procedure

Because of the proprietary nature of green roofs, a design procedure is not provided.

G. Additional Resources

Berndtsson, J.C., Bengtsson, L., 10th International Conference on Urban Drainage, Copenhagen/Denmark. The Influence of Extensive Vegetated Roofs on Runoff Water Pollution Loads. August 2005.

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission. http://www.georgiastormwater.com/

Greenroofs.com Contains: Green Resource News, Upcoming events, recommended readings, latest news about green roofs including projects and research links. http://www.greenroofs.com/

Greenroofs.org Contains: Official website of Green Roofs for Healthy Cities. Information about green roofs, installation, benefits and demonstration projects. http://www.greenroofs.org/ .

Green Roofs for Healthy Cities (GRHC) Green Roof Design 101 Course Participant Manual. June 2004.

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

RoofScapes Inc. http://www.roofmeadow.com/

Vermont Stormwater Management Manual. 2002. http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004. http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004. http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

RAINWATER HARVESTING



Residential rain barrel - Stillwater, MN

Definition:
Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. There are a number of systems used for the collection, storage and distribution of rain water including rain barrels, cisterns, evaporative control systems, and irrigation.

KEY CONSIDERATIONS

Design Criteria:

- The system should be watertight, have a smooth interior surface, be located on level and stable ground, have a tight-fitting lid, good screens on the inlet and outlet and have an emergency overflow device.
- To prevent the breeding of mosquitoes, empty the water in less than 5 days or place a fine screen over all openings.
- Material can withstand the pressure of water over long periods of time.
- Disconnect and drain rain barrels and cisterns in the winter to prevent freezing and deformation of the rain water harvesting system.

Benefits:

- Protects water supplies by reducing use during peak summer months.
- Mimics the natural hydrology of the area by infiltrating a portion of the rain water falling on the site.
- Reduces volume of storm water being delivered to downstream waterbodies.
- Results in cost savings by reducing municipal water bill.

Limitations:

- Not suitable for the following roof types: tar and gravel, asbestos shingle and treated cedar shakes.
- Depending on the design, requires a certain amount of operation and maintenance.
- Proprietary systems can be expensive.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration
X*	Screening/ Filtration
X	Temperature Control
X	Settling
X	Evaporation
X*	Transpiration
X*	Soil Adsorption
X*	Biological/ Micro. Uptake

POLLUTION REMOVAL

100%*	Total Suspended Solids
100%*	Nutrients - Total Phosphorus/ Total Nitrogen
100%*	Metals - Cadmium, Copper, Lead, and Zinc
100%*	Pathogens - Coliform, Streptococci, E. Coli
100%*	Toxins - Chloride, Hydrocarbons, Pesticides

**Assuming water is drained to a vegetated pervious area. Does not apply to volume of runoff that bypasses the system*

SITE FACTORS

Rooftop	Drainage Area
NA	Max. Slope
NA	Min. Depth to Bedrock
NA	Min. Depth to Water Table
NA	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Poor	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff

Description:
Rain water harvesting can be accomplished using rain barrels and/or cisterns. Rain barrels are typically located at the downspout of a gutter system and are used to collect and store rainwater for watering landscapes and gardens. The simplest method of delivering water is by the force of gravity. However, more complex systems can be designed to deliver the water from multiple barrels connected in a series with pumps and flow control devices. Cisterns have a greater storage capacity than rain barrels and may be located above or below ground. Due to their size and storage capacity, these systems are typically used to irrigate landscapes and gardens on a regular basis reducing the strain on municipal water supplies during peak summer months. Again, cisterns may be used in series and water is typically delivered using a pump system. The storage capacity of a rain barrel or cistern is a function of the catchment area, the depth of rainfall required to fill the system and the water losses. A general rule of thumb in sizing rain barrels or cisterns is that one inch of rainfall on a 1,000 square foot roof will yield approximately 600 gallons of runoff.

A. Suitability

General

Rain water harvesting is the practice of collecting rain water from impermeable surfaces, such as rooftops, and storing for future use. There are a number of systems used for the collection, storage and distribution of rain water but they generally fall into two categories; rain barrels and cisterns.

Function Within Stormwater Treatment Train

Rain water harvesting is one of the first steps in the treatment train. It can be designed to provide stormwater reduction and detention. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- ► reduce stormwater pollutants
- ► decrease runoff peak flow rates
- ► decrease the volume of stormwater runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Storage should be provided so that rainfall is collected and stored and then released during periods of dry weather. Volume reduction may be applied to the 5-year 24-hour standard for the total volume that can be stored. An operation and maintenance plan must be approved by the city engineer to ensure that the volume is available for most runoff events.

The following terms are thus used in the text to distinguish various levels of rainwater harvesting design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

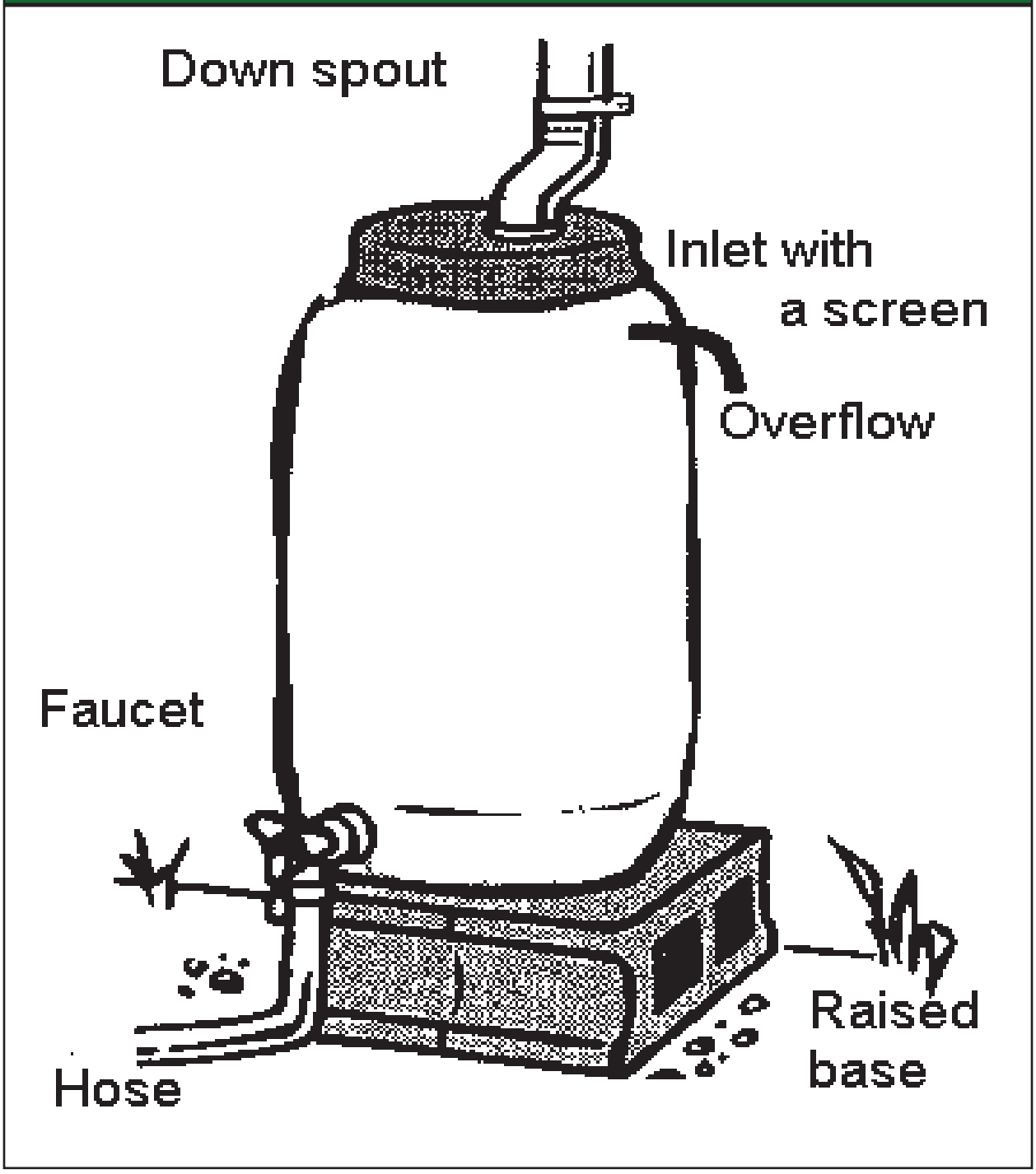
Design Variants

Rain water harvesting can be accomplished using rain barrels and/or cisterns.

Rain Barrel

Rain barrels are typically located at the downspout of a gutter system and are used to collect and store rainwater for watering landscapes and gardens. The simplest method of delivering water is by the force of gravity. However, more complex systems can be designed to deliver the water from multiple barrels connected in a series with pumps and flow control devices. A typical rain barrel is shown in Figure 8.3.

Figure 8.3 Typical Rain Barrel Design

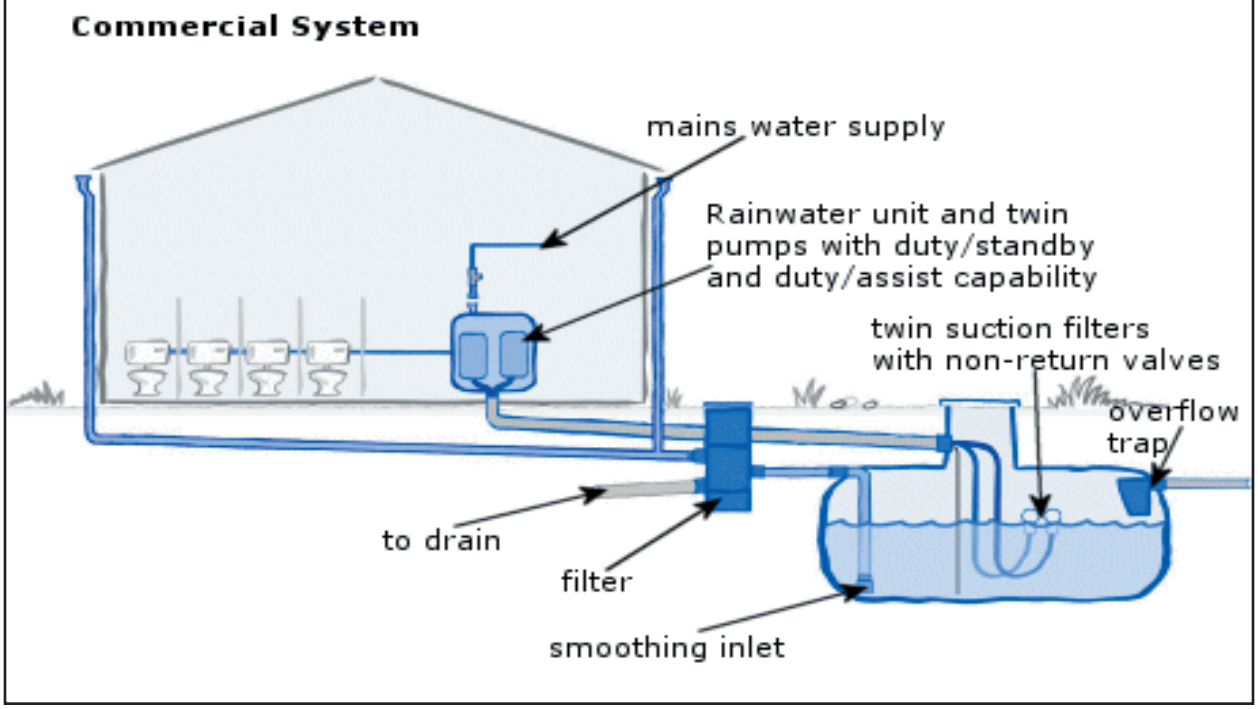


Source: Ottawa City Services

Cistern

Cisterns have a greater storage capacity than rain barrels and may be located above or below ground. Due to their size and storage capacity, these systems are typically used to irrigate landscapes and gardens on a regular basis reducing the strain on municipal water supplies during peak summer months. Again, cisterns

Figure 8.4 Typical Cistern Design



Source: Rainwater Harvesting Systems, Inc.

may be used in series and water is typically delivered using a pump system. A typical cistern is shown in Figure 8.4.

Retrofit Suitability

Rainwater harvesting retrofits are easily applied to existing buildings. Rain water harvesting is a highly desirable retrofit practice in watersheds that are concerned about reducing water quantity.

Cold Climate Suitability

Rainwater harvesting is suitable for cold climates but some systems can only be used in summer conditions. Disconnect and drain rain barrels and cisterns in the winter to prevent freezing and deformation of the rain water harvesting system.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the rainwater harvesting configuration and the rate of use. Rain water harvesting reduces volume by capturing runoff from impervious areas, generally rooftops.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirement when rain water harvesting is used. However, these practices can help reduce the overall volume that requires treatment.

Water Quality Treatment

When stormwater is harvested and applied to a pervious vegetative surface, it removes pollutants through filtration, soil adsorption, and biological uptake. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Pollutant removal data for select parameters is provided in Table 8.11.

Table 8.11. Percent Removal of Key Pollutants by Rain Water Harvesting

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals [%]	Bacteria [%]	Hydro-carbons [%]
Rain water harvesting	100*	100*	100*	100*	100*	100*

Notes
* If water is drained to a vegetated area. Does not apply to volume of runoff that bypasses the system

Source: MPCA, 2005

Limitations

The following general limitations should be recognized when considering installation of a rainwater harvesting system:

- Not suitable for the following roof types; tar and gravel, asbestos shingle and treated cedar shakes.
- Depending on the design, requires a certain amount of operation and maintenance.
- Proprietary systems can be expensive.

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use rainwater harvesting for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgement as to whether or not a rainwater harvesting technique is the appropriate BMP for the site.

- ***Drainage Area*** – Rooftop
- ***Site Topography and Slopes*** – NA
- ***Soils*** – NA
- ***Depth to Ground Water Table and Bedrock*** – NA
- ***Site Location / Minimum Setbacks*** – consider routing overflow away from building foundation
- ***Karst*** – NA

Conveyance

Stormwater is conveyed to the rainwater harvesting system by a downspout. The system fills to capacity and excess water is released by an overflow outlet. Water is removed from the storage chamber by a pump or gravity drain. An overflow should be provided for storms that exceed the design storm.

Pretreatment

- Rain water harvesting systems should have a screen at the end of the downspout to prevent clogging.

Treatment

The following guidelines are applicable to the actual treatment area of the rainwater harvesting device.

- ***Space Occupied*** – Large installations can be underground. Small residential units are generally above ground and space is dictated by the amount of runoff expected to be collected.
- ***Practice Slope*** – NA
- ***Side Slopes*** – NA
- ***Depth*** – NA
- ***Groundwater Protection*** – NA
- ***Aesthetics*** – Rain barrels can be designed to be aesthetically pleasing and come in many different styles. Rain water harvesting can also be effectively integrated into the site planning process to be unseen (underground) or can be surrounded by vegetation to be inconspicuous.

Landscaping

- Rain water harvesting is often used as the water source for gardens, lawns and landscaping features. Harvested water can also be used for a water feature such as a fountain.

Safety

- If maintained or designed poorly a rain barrel can act as a breeding ground for mosquitoes. Rain barrels should be drained within 5 days to prevent mosquito breeding grounds. Rain barrels fitted with a screen may not need to be drained as often provided that the mesh pattern is fine enough to prevent mosquito entry.
- Water from rainwater harvesting systems should not be used directly on consumable vegetables because of the risk of contamination from bird dropping on roofs, and toxins from roofing materials.
- Rain barrels should have a locking lid to prevent children and animals from entering and drowning.

C. Construction Specifications

Construction of rain water harvesting practices incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that for cisterns a contractor experienced in rainwater harvesting construction be contracted for the final design plans and specifications. It is generally not necessary to hire a contractor for small residential systems.

D. Operation and Maintenance

Overview

Effective long-term performance of rain water harvesting requires a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED). An operating plan must be filed with the city before stormwater reduction credit will be received. Operating plans should include the maximum time that water will be stored, type and size of area that the water will be used, and location of the emergency overflow.

Construction and Maintenance Costs

Table 8.12 is a list of the general components used in construction of this practice. Utilizing Table 8.12 will allow designers to avoid over or under estimation of fixed costs.

Table 8.12 Rainwater Harvesting Cost Components		
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**
Structural Components	Downspouts	($/structure)
	Screening	($/structure)
	Piping	($/structure)
	Pumps	($/structure)
	Storage Chambers	($/structure)
	Valves, hoses	($/structure)
	Lid and locking mechanism	($/structure)
Annual Operation, Maintenance, and Inspection	Removing Sediments	Removal Cost
	Cleaning Screens	($/screen)
	Winterizing system	($/year)
	Pump Maintenance (cisterns only)	($/year)

E. Links to Other Manuals

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005.
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

F. References

Center for Disease Control. Stormwater Management and Vector Breeding Habitats.
http://www.cdc.gov/nceh/ehs/Docs/Stormwater-Factsheet.pdf

Pamela Shubat. Minnesota Department of Health, 2006

Ottawa City Services. How to make your own rain barrel.
http://www.ottawa.ca/city_services/water/efficiency/rain_barrel_en.shtml

Rainwater Harvesting Systems, Inc UK Rainwater Harvesting Association
http://www.rainharvesting.co.uk/systems/commercial.htm Accessed Online June 27, 2006

PERVIOUS SURFACES



Grasspave® at Bradshaw Celebration of Life Center - Stillwater, MN

Definition:
Pervious pavements reduce the amount of runoff by allowing water to pass through surfaces that would otherwise be impervious. Water can either infiltrate into the ground, if soil permeability rates allow, or be conveyed to other BMPs or a storm water system by an under-drain.

KEY CONSIDERATIONS

Design Criteria:

- Pervious pavement is typically used in low traffic areas including overflow parking areas, emergency vehicle lanes, and pedestrian areas.
- In-situ soils should have field-verified minimum permeability rates greater than 0.3 in./hr. Contributing runoff from offsite should be limited to a 3:1 ratio of impervious area to pervious pavement area.
- The selected systems load bearing surface should be suited to maximum intended loads.
- Design storms should be infiltrated within 72 hours (48 hours to meet MPCA requirements)

Benefits:

- Good for highly impervious areas – particularly parking lots.
- Reduces need for other storm water BMPs by reducing runoff.
- Construction costs of some systems are less than traditional paving.
- Soil-enhanced turf systems resist compaction, increase infiltration, and provide soils for healthier vegetation.

Limitations:

- Construction costs of some systems are more expensive than traditional paving
- Use depends on infiltration rates of underlying soils.
- Maintenance costs are higher than conventional paving.
- Not recommended for high traffic areas because of durability concerns.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate site conditions
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X*	Transpiration *if vegetation present
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA*	Total Suspended Solids *pretreatment for TSS is recommended if adjacent areas drain to pervious pavement
80%/ 80%	Nutrients - Total Phosphorus/ Total Nitrogen
90%	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbons, Pesticides

Note: Pollution removal percentages apply to volume of runoff treated, and not to volume of runoff bypassed

PERVIOUS SURFACES

SITE FACTORS

NA	Drainage Area
2% Max.	Max. Slope
3 ft	Min. Depth to Bedrock
3 ft	Min. Depth to Water Table
A,B	SCS Soil Type *can be used in C&D soil types with modifications (e.g. underdrains)
Good	Freeze/ Thaw Suitability *with adequate sub-grade
Yes	Potential Hotspot Runoff *requires impermeable liner if identified in hotspot area

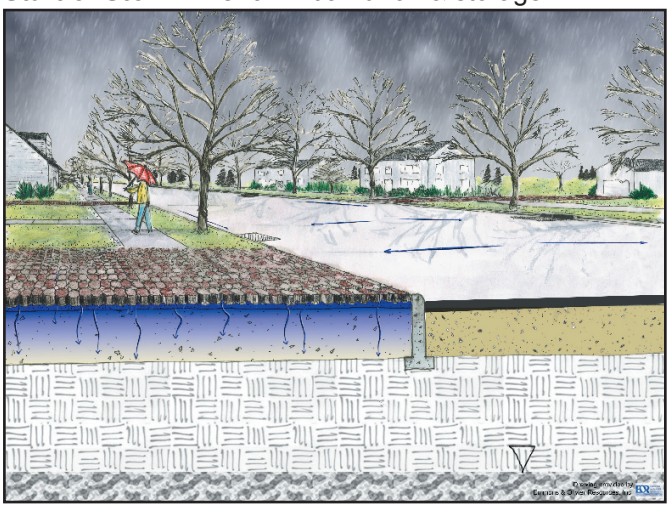
Description:
Pervious pavements can be subdivided into three general categories: 1) **Porous Pavements** – porous surfaces that infiltrate water across the entire surface (i.e. porous asphalt and porous concrete pavements); 2) **Permeable Pavers** – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.); 3) **Amended Soils** - Fiber or artificial media added to soil to maintain soil structure and prevent compaction. There are many different types of modular porous pavers available from different manufacturers.

Pervious pavement systems reduce runoff from impervious surfaces by allowing stormwater to pass through the load bearing surface and infill that are selected based upon the intended application and required infiltration rate. Runoff is stored in the stone aggregate base course/ storage layer, if present, and allowed to infiltrate into the surrounding soil (functioning like an infiltration basin), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter).

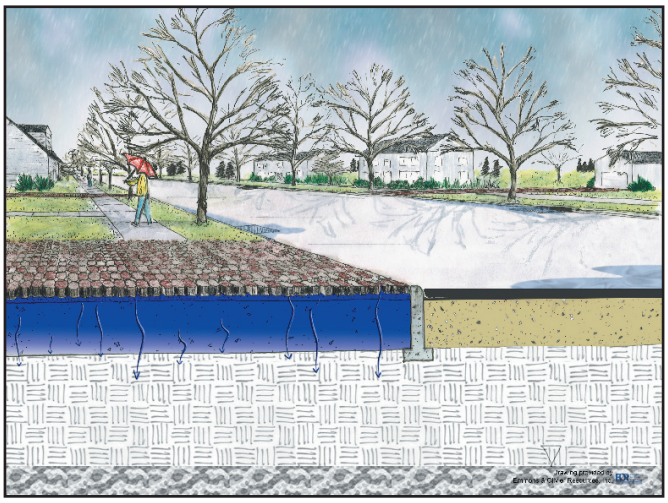
Regular maintenance of pervious pavements is necessary to ensure long-term effectiveness. Annual or semi-annual sweeping or vacuuming of surface debris (litter, sediment, etc.) is HIGHLY RECOMMENDED for pavement or pavers. If clogging occurs, the filtration media below the surface may need to be replaced. Manufacturers should be consulted for specific maintenance requirements.

STORM SEQUENCE

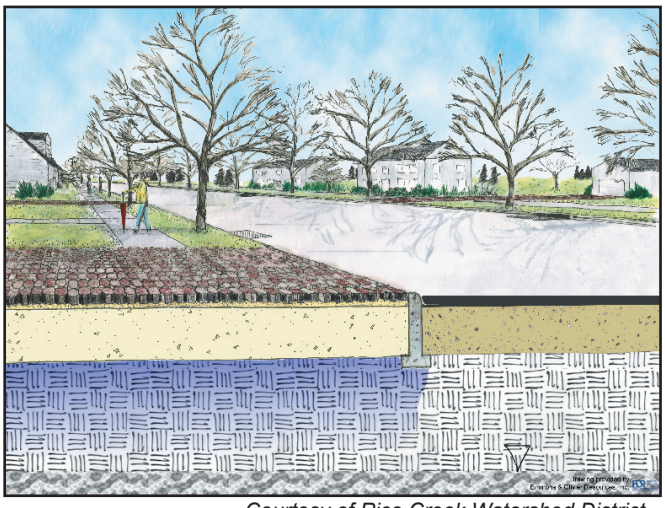
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Pervious surfaces reduce the amount of stormwater runoff generated on a site by allowing water to pass through surfaces that would otherwise be impervious. Water can either infiltrate into the ground, if soil permeability rates allow, or be conveyed to other BMPs or a storm water system via an under-drain.

Some types of pervious surfaces may work well on residential and arterial roads but generally pervious surfaces are used in areas with low traffic loads. The most popular applications of pervious surfaces are:

- Overflow parking for commercial sites
- Private roads and driveways
- Intermittently used facilities that require large parking areas (churches, stadiums, auditoriums)
- Emergency vehicle lanes

Function Within Stormwater Treatment Train

Pervious surfaces are one of the first steps in the treatment train. They can be designed to provide stormwater reduction, detention and cooling. The practice may be applied as part of a stormwater management system to achieve the following objectives:

- reduce stormwater pollutants
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of permanent pervious surface such as brick pavers, pervious concrete/asphalt or other technique as approved through the City of Inver Grove Heights Stormwater Manual (Subd. 39 H.3.a)

Where possible, pervious surfaces should be designed for volume control. Storage should be provided below the pervious surface in the form of gravel or other underground storage medium. Volume reduction may be applied to the 5-year 24-hour standard for any storage provided below the underground storage overflow elevation. Additionally, volume credit may be allowed for different configurations of pervious surfaces but the amount of volume credit will be based on substrate properties, paver layout, and other properties and will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of pervious surface design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Pervious surfaces can be subdivided into three general categories:

1) ***Porous Pavements*** – porous surfaces that absorb water across the entire surface (i.e. porous asphalt and porous concrete pavements);

2) ***Permeable Pavers*** – impermeable modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.). There are many different types of modular porous pavers available from different manufacturers.

3) ***Reinforced Soil*** - Fiber or artificial media added to soil to maintain soil structure and prevent compaction. Generally a structural matrix made of plastic or metal that absorbs the weight of vehicles and pedestrians and leaves the soil uncompacted. This variant does not include amending soils with mulch or other organics, for more information on amended soils see the soil amendment section in this chapter.

Retrofit Suitability

Pervious surface retrofits are popular when an existing impervious surface will be upgraded or replaced. They also provide a great option for expanding parking lots that are intermittently used.

Cold Climate Suitability

The freeze/thaw suitability of pervious surfaces is as good as conventional pavement as demonstrated by the many successful examples throughout the twin cities.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the pervious surface configuration. Pervious surfaces can be designed to reduce volume through infiltration if the underlying soils permit.

In general, supplemental stormwater practices will likely be necessary to satisfy volume control requirements when pervious surfaces are used. However, these practices can help reduce volume requirements for a site through volume reduction and retention.

Pervious surface systems reduce runoff from impervious surfaces by allowing stormwater to pass through the load bearing surface and infill that are selected based upon the intended application and required infiltration rate. Runoff is stored in the stone aggregate base/storage layer, if present, and allowed to infiltrate into the surrounding soil (functioning like an infiltration basin), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter).

Water Quality Treatment

Pervious surfaces can remove stormwater pollutants through chemical and bacterial degradation, sorption, and filtering. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Due to the logistical challenges presented in structuring a runoff quality study, the number of scientific studies documenting the pollutant removal capability of pervious surfaces is limited. However, pollutant removal and effluent concentration data for select parameters are provided in Table 8.13.

Table 8.13. Percent Removal of Key Pollutants by Practices

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals [%]	Bacteria [%]	Hydro-carbons [%]
Pervious Surfaces	NA*	80	80	90	ND	ND

Notes
* Pretreatment for TSS is recommended if adjacent areas drain to pervious surfaces
ND: No Data

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of a pervious surface system:

- Not recommended for high traffic areas
- Construction costs of some systems are more expensive than traditional paving
- Ability to use it for stormwater volume reduction credit depends on infiltration rates of underlying soils
- Maintenance needs can be higher than conventional paving

B. Major Design Elements

Physical Feasibility Initial Check

- ***Site Topography and Slopes*** – 2% maximum slope to allow adequate time for absorption.
- ***Soils*** – Underlying soils should be HSG A or B for infiltration designs. C and D soils are sufficient if infiltration is not a priority.
- ***Depth to Ground Water Table and Bedrock*** – Minimum 3 feet from bottom of the practice to the seasonally high water table or bedrock.

Conveyance

It is HIGHLY RECOMMENDED that a pervious surface system have slopes less than 2% and underlying soils that have field verified infiltration rates of 0.3 in/hour or greater. These criteria allow the water to be conveyed vertically to recharge groundwater. When excessive rainfall beyond the capabilities of the underlying soils occurs, water should drain to additional BMPs or offsite to a stormwater management system.

Pretreatment

- Routing water from adjacent impervious areas to pervious surfaces will be allowed if approved by the city engineer. Water routed to pervious surfaces from other impervious areas requires pretreatment for TSS or city approval. Contributing runoff from offsite should be limited to a 3:1 ratio of impervious area to pervious surface area.

Treatment

- ***Space Occupied*** – Parking areas, roads, driveways and patios are the most common spaces occupied by pervious surfaces. Regularly used for retrofits because it utilizes existing space.
- ***Practice Slope*** – <2%
- ***Side Slopes*** – NA
- ***Depth*** – Variable based on site soils, depth of aggregate and type of surface used.
- ***Groundwater Protection*** – It is required that runoff from potential stormwater hotspots not be infiltrated unless adequate pre-treatment has been provided. Infiltration of runoff from confirmed hotspot areas, industrial areas with exposed significant materials or vehicle fueling and maintenance areas is PROHIBITED.
- ***Aesthetics*** – Pervious surfaces can be integrated into the site planning process, and aesthetically designed using decorative pavers. Or they can be designed to look similar to conventional paving systems.

Landscaping

- Depressed parking lot islands are an aesthetic and functional compliment to pervious surface parking lots.
- It is HIGHLY RECOMMENDED that vegetation surrounding pervious surfaces be regularly maintained and bare areas seeded.

Safety

- Porous pavement systems have the same safety considerations as conventional paving systems.
- OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites: http://www.osha.gov/pls/oshaweb/

Construction Details

Because of the proprietary nature of pervious surface systems, no construction details are provided.

C. Construction Specifications

Given that the construction of pervious surfaces incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
   - Installation prior to site disturbance
   - Catch basin/inlet protection

II. Excavation, Backfill and Grading
   - Gravel filter specifications (if required)
   - Filter fabric specifications (if required)

III. Construction Sequence Scheduling
- ► Temporary construction access
- ► Location of silt fence installation to protect BMPs and downgradient receiving waters
- ► Construct pervious surface system
- ► Seeding and mulching disturbed areas
- ► Site stabilization
- ► Silt fence removal

IV. Construction Observation
- ► Adherence to construction documents
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

Effective long-term performance of pervious surfaces can be ensured by completing a performance monitoring plan (RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The monitoring plan should address the following items: inspection and efficiency assessment, water quality and quantity monitoring of runoff leaving the pervious surface, and physical damages.

Elements to be considered for the development of a maintenance plan are broken into the following categories: Construction Phase Maintenance Considerations; and Post-Construction Maintenance Considerations. In general terms, the most frequently cited maintenance concern for pervious surfaces is clogging caused by organic matter and fine silts.

Construction Phase Maintenance Considerations

Pervious surfaces that are expected to infiltrate stormwater are particularly vulnerable during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the practice. In addition, construction with heavy equipment can result in compaction of the soil, which can then reduce the underlying soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Critical construction elements for pervious surfaces are as follows:

- ► ***Avoid excessive compaction***
  It is REQUIRED that in order to prevent soil compaction, the proposed pervious surface area be staked off and marked during construction to prevent heavy equipment and traffic from traveling over it and so that the practice area is not used as a construction staging area.
- ► ***Stabilize Vegetation Before and After Construction***
  Excessive sediment loadings can occur without the use of proper erosion and sediment control practices during the construction process. It is REQUIRED that upland drainage areas be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads. If pervious surfaces are in-place during construction activities, it is REQUIRED that sediment and runoff be kept away from the area, such as with diversion berms and soil-stabilizing vegetation around the perimeter of the surface.
- ► ***Keep Pervious Surfaces "Off-line" until Construction Is Complete***
  It is REQUIRED that sediment and runoff be kept completely away from the pervious surfaces during construction. Thus, pervious surfaces should never serve as sediment control devices during site construction. It is HIGHLY RECOMMENDED that construction of pervious surfaces be suspended during snowmelt or rainfall, in order to prevent soil smearing, clumping, or compaction.

- ***Inspections***
  Inspections during construction are needed to ensure that the pervious surface is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's interpretation of the plan is acceptable to the designer.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of pervious surfaces necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Chapter 10.

- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the City of Inver Grove Heights.
- Adequate access must be provided for all pervious surfaces for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.

Construction and Maintenance Costs

Table 8.14 is a list of the general components used in construction of this practice. Utilizing Table 8.14 will allow designers to avoid over or under estimation of fixed costs.

Table 8.14 Pervious Surface Cost Components

Implementation Stage	Primary Cost Components	Basic Cost Estimate
Structural Components	Pervious Surface	($/square foot)
	Outflow components	($/structure)
	Stone aggregate storage layer	($/cubic yard)
	Underdrain (if used)	($/Linear Foot)
Annual Operation, Maintenance, and Inspection	Sweeping	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Vacuuming	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)

Design Procedure

Because of the proprietary nature of pervious surfaces, a design procedure is not listed.

E. Additional Resources

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Minnesota Pollution Control Agency. The Minnesota Stormwater Manual. 2005.
http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html#manual

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

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FILTRATION



Lino Lakes City Hall - Lino Lakes, MN



City of Woodbury, MN

Definition:
Structural stormwater controls that capture, temporarily store, and route stormwater runoff through a filter bed to improve water quality.

KEY CONSIDERATIONS

Design Criteria:

- Ensure adequate space for filtration system
- Some installations require 2-6 feet of head
- Removal potential of the key pollutant
- Parent material and potential for ground water contamination

Benefits:

- Good for highly impervious areas with low sediment/high pollutant load (e.g. urban land use and retrofit scenarios)
- High pollutant removal rates
- May be used in a variety of soil types
- Good for the treatment of hotspots because it can be isolated from ground water if contamination concerns exist

Limitations:

- Higher maintenance requirements
- Some installations (media filters) have higher construction costs
- Potential to cause odor problems
- Minimal treatment of soluble nutrients
- Potential for nitrification in media filters where anaerobic conditions exist

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate soil & site conditions
X	Screening/ Filtration
	Temperature Control
	Settling
X	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

85%	Total Suspended Solids
50%/35%	Nutrients - Total Phosphorus/ Total Nitrogen
50%	Metals - Cadmium, Copper, Lead, and Zinc
35%	Pathogens - Coliform, Streptococci, E. Coli
80%	Toxins - Chloride, Hydrocarbon, Pesticide

SITE FACTORS

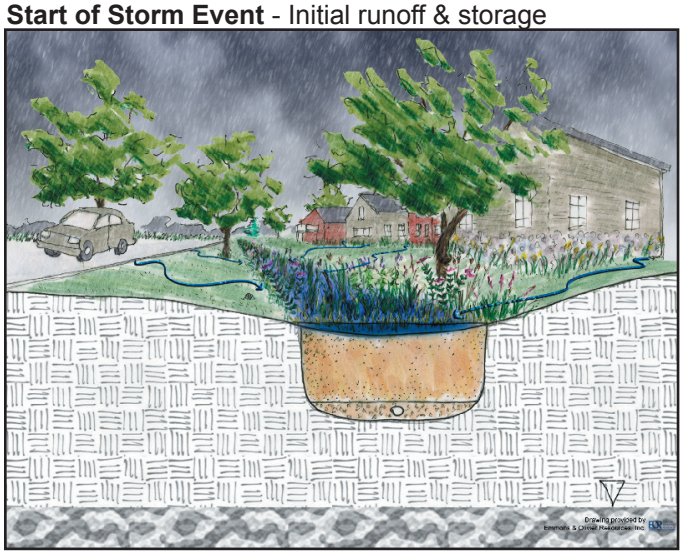
5 AC Max	Drainage Area
20%	Max. Site Slope
3’	Min. Depth to Bedrock
3’	Min. Depth to Seasonally High Water Table
A,B,C,D	NRCS Soil Type
Poor - Good	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff *requires impermeable liner

Description:
Filtration systems vary in their operation and applicability, but all can be described as structural BMPs that function mainly to enhance water quality by passing stormwater through a media. The media can be made of sand, peat, grass, soil, compost or vegetation and should be assigned on a case-by-case basis. Filters can be off-line systems or designed as pre-treatment before discharging to other stormwater features.

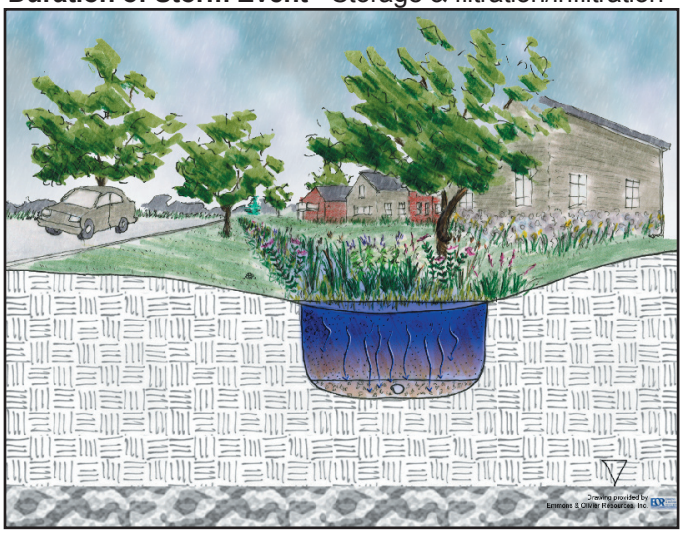
The two main categories of filtration systems include: media filters, and vegetated filters. Media filters can be located on the surface, underground, along the perimeter of an area, or in what is called a pocket design. Vegetated channels may be grass channels, dry or wet swales, submerged gravel wetlands, or filter strips.

STORM SEQUENCE

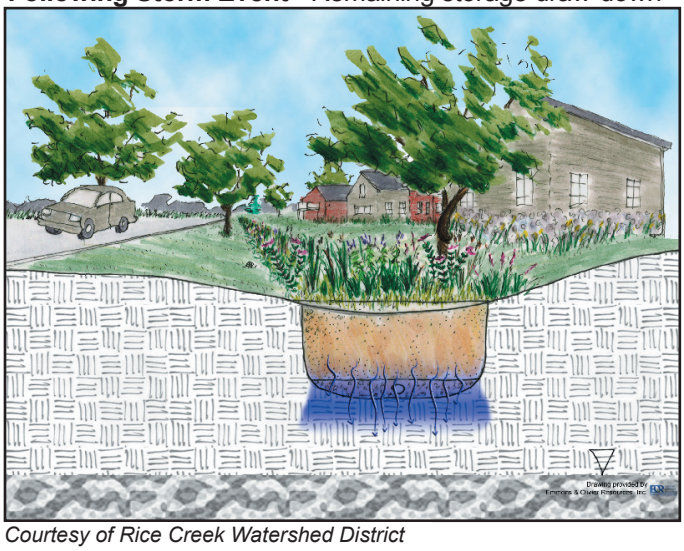
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Filtering practices include media filters (surface, underground, perimeter), vegetative filters (filter strips, grass channels), and combination media/vegetative filters (dry swales). Media and media/vegetative filters operate similarly and provide comparable water quality capabilities as bioretention. Vegetative filters are generally more suitable as pretreatment practices, but in some situations can be used on a standalone basis.

Filtering practices have widespread applicability and are suitable for all land uses, as long as the contributing drainage areas are limited (e.g., typically less than 5 acres). Media filters are not as aesthetically appealing as bioretention, which makes them more appropriate for commercial or light industrial land uses or in locations that will not receive significant public exposure. Media filters are particularly well suited for sites with high percentages of impervious cover (e.g., > 50%). Media filters can be designed with an underdrain, which makes them a good option for treating potential stormwater hotspots (PSHs). They can also be installed underground, to prevent the consumption of valuable land space (often an important retrofit or redevelopment consideration). Vegetative filters can be incorporated into landscaped areas, providing dual functionality.

Function Within Stormwater Treatment Train

Media filtration systems are designed primarily as off-line systems for stormwater quality and typically are used in conjunction with another structural control. Vegetative filters, designed as grass channels or swales, may be the main form of conveyance between or out of BMPs, as well as providing treatment for stormwater runoff.

Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Filtering devices generally may be used to meet the Inver Grove Heights pretreatment requirements. Stormwater filtering systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Additional volume credit may be allowed (such as a swale that doesn't contain storage areas, but has a fast infiltration rate) but the amount of volume credit will need to be approved by the city engineer.

The following terms are thus used in the text to distinguish various levels of filtration practice design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants (Adapted from Georgia Stormwater Manual and Center for Watershed Protection)

As filtration becomes a more common tool in stormwater management, and as the number of design variants increases, so does the number of names for each of these variants. For example:

- Sand filters are also referred to as filtration basins, filter systems, first-flush filtration, or media filtration systems.
- Grass channels are also referred to as biofilters. (Seattle METRO, 1992 from CWP)
- Dry swales are also referred to as grassed or vegetated swales.

The following types of filtration systems can be used depending upon project scale and site conditions:

Media Filters

- ***Surface Sand Filter*** – For a surface sand filter, a flow splitter is used to divert runoff into an off-line sedimentation chamber. The chamber may be either wet or dry, and is used for pretreatment. Runoff is then distributed into the second chamber, which consists of a sand filter bed (~18") and temporary runoff storage above the bed. Pollutants are trapped or strained out at the surface of the filter bed. The filter bed surface may have a sand or grass cover. A series of perforated pipes located in a gravel bed collect the runoff passing through the filter bed, discharge it to the next downstream BMP. If underlying soils are permeable, and groundwater contamination unlikely, the bottom of the filter bed may have no lining, and the filtered runoff may be allowed to infiltrate.
- ***Underground Sand Filter*** – The underground sand filter was adapted for sites where space is at a premium. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The vault can be either on-line or off-line in the storm drain system. The first chamber is used for pretreatment and relies on a wet pool as well as temporary runoff storage. It is connected to the second sand filter chamber by an inverted elbow, which keeps the filter surface free from trash and oil. The filter bed is 18 inches in depth and may have a protective screen of gravel or permeable geotextile to limit clogging. During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir. Filtered runoff is collected, using perforated underdrains that extend into the third "overflow" chamber.
- ***Perimeter Sand Filter*** – The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber, which has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, which consists of a sand layer (12"-18"). During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The remaining runoff is filtered through the sand, and collected by underdrains and delivered to a protected outflow point.

Vegetative Filters

- ***Grass Channels*** – Grass channels can be designed to meet a runoff velocity target for a water quality storm as well as the peak discharge from a 2-year design storm. Grass channels can be designed to pass larger storms and serve as conveyance tools. Pretreatment can be created by placing checkdams across the channel below pipe inflows, and at various other points along the channel. Grass channels do not provide adequate pollutant removal benefits to act as a stand-alone BMP.
- ***Dry Swales*** – In dry swales, additional volume can temporarily be retained by checkdams during each storm. Unlike the grass channel, the filter bed in the swale is 30 inches of prepared soil. Water is filtered through the sandy loam to underdrains and the swale is quickly dewatered. In the event that surface soils clog, the dry swale has a pea gravel window on the downstream side of each checkdam to route water to the underdrain. Dry swales are often preferred in residential areas because they prevent standing water.
- ***Wet Swales*** – Wet swales occur when the water table is located very close to the surface. This wet swale acts as a very long and linear shallow wetland treatment system. Like the dry swale, additional

stormwater volume is stored within a series of cells created by checkdams. Cells may be planted with emergent wetland plant species to improve pollutant removal.

- ***Filter Strips*** – Filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. To be effective, however, filter strips require the presence of sheet flow across the entire strip. Once flow concentrates to form a channel, it effectively short-circuits the filter strip. In the most common design, runoff is directed from a parking lot into a long filtering system composed of a stone trench, a grass strip and a longer naturally vegetative strip. In addition, a stone drop can be located at the edge of the parking lot and the filter strip to prevent sediments from depositing at this critical entry point. The filter strip is typically an on-line practice, so it must be designed to withstand the full range of storm events without eroding. Filter strips do not provide adequate pollutant removal benefits to act as a stand-alone BMP.

Other Filters Not Approved For Inver Grove Heights

The following filters are not approved for use in Inver Grove Heights due to **high probability of failure** under cold climate conditions. They are included here for informational purposes only.

- ***Organic Filter*** – The organic filter functions in much the same way as the surface sand filter, but uses leaf compost or a peat/sand mixture as the filter media instead of sand (peat should not be used when the target pollutant for removal is a dissolved nutrient). The organic material enhances pollutant removal by providing adsorption of heavy metals. In an organic filter, runoff is diverted with a flow splitter into a pretreatment chamber, from which it passes into one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by a filter fabric and perforated pipe and gravel. Runoff filters through the organic media to the perforated pipe and ultimately to the outlet. The filter bed and subsoils can be separated by an impermeable polyliner to prevent movement into groundwater.
- ***Pocket Filter*** – Pocket sand filters are intended as an inexpensive utilization of sand filters where sediment loads do not warrant a sedimentation chamber and can suffice with a grass filter strip and a plunge pool. The filter bed is comprised of a shallow basin containing the sand filter medium. The filter surface is a layer of soil and a grass cover. In order to avoid clogging the filter has a pea gravel “window” which directs runoff into the sand and a cleanout and observation well. Typically the filtered runoff is allowed to exfiltrate to groundwater, although underdrains may be needed if the soils are not suitably permeable.
- ***Submerged Gravel Wetland*** – Submerged gravel filters consist of a series of cells that are filled with crushed rock or gravel. The standpipe from each cell is set at an elevation that keeps the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. The anaerobic conditions on the bottom of the filter can foster the de-nitrification process. Submerged gravel wetlands are not recommended for stormwater quality in cold climate conditions, although they have been used in Minnesota for effluent polishing of wastewater.

Retrofit Suitability

The use of filters as a retrofit practice primarily depends on existing infrastructure and the compatibility of existing storm drain inverts that need to connect to the filter underdrain outflow. In general, four to six feet of elevation above the existing collection system invert is needed for media filter retrofits (2-3 feet is needed for perimeter filters). Underground media filters are excellent for ultra-urban settings where space is at a premium.

Cold Climate Suitability

Various options for use of filtration are available for treating snowmelt runoff. Some of the installations are built below the frost line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is HIGHLY RECOMMENDED for surface systems.

The problem with filtration in cold weather is the ice that forms both over the top of the facility and within the soil interstices. To avoid these problems to the extent possible, it is HIGHLY RECOMMENDED that the facility be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods, including limiting inflow, under-drainage, and surface disking.

Proprietary, sub-grade filtration systems provide an alternative to standard surface based systems. Essentially, these systems provide an insulated location for snowmelt to be stored and filtered. The insulating value of these systems adds to their appeal as low-land-consumption alternatives to other BMPs.

Water Quantity Treatment

Filters are not typically a primary practice for providing water quantity control. They are normally configured to safely pass large storm flows while still protecting the filter bed. Vegetative filters, in particular, can help reduce stormwater volume control standard for a site by providing volumetric losses from infiltration and evapo-transpiration. Generally, however, to meet site water quantity criteria, it is HIGHLY RECOMMENDED that another structural control be used in conjunction with a filter.

Water Quality Treatment

Filters are an excellent stormwater treatment practice with the primary pollutant removal mechanism being filtering and settling. Less significant processes can include evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal and effluent concentration data for select parameters are provided in Tables 8.15 and 8.16, respectively. While it is possible to design media filters to discharge a portion of the effluent to the groundwater, they are typically designed as enclosed systems (i.e., no “infiltration”). Vegetative filters, on the other hand, can readily be designed as an effective infiltration / recharge practice, particularly when parent soils have good permeability (> ~ 0.5 in/hr). Consult the Pretreatment section on page 71 for more guidance on how to use filters to meet pretreatment water quality and recharge criteria.

Table 8.15 Percent Removal of Key Pollutants by Practice Group

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Filtering Practices[2]	85	60	35[1]	60	35	80

Notes
1. Based on fewer than five data points (i.e., independent monitoring studies)
2. Higher removal rates for dry swales.

Removals represent median values

Source: Winer, 2000

Table 8.16 Typical BMP Best Performance Effluent Concentrations					
Practice	**TSS**	**TP**	**TN**	**Cu[1]**	**Zn[1]**
Filtering Practices	14	0.2	1.1	8	60

Notes
1. Units for Zn and Cu are micrograms per liter
2. Values from ASCE bmp database and Winer 2000 (shaded values)

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of a filtration practice:

- Nitrification of water in media filters may occur where aerobic conditions exist
- Offers limited water quantity control
- Potential to create odors

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a filtration device for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgment as to whether or not a filtration device is the appropriate BMP for the site.

- ***Drainage Area*** – 5 acres maximum RECOMMENDED (0.5 to 2 acres is ideal). Surface sand filters can sometimes be sized for drainage areas up to 10 acres, but only with rigorous and committed maintenance schedules, among other design and O&M considerations.
- ***Site Topography and Slopes*** – It is RECOMMENDED that sloped areas immediately adjacent to practice be less than 20% but greater than 1%, to promote positive flow towards the practice.
- ***Soils*** – No restrictions for media filters with underdrain is needed.
- ***Depth to Water Table and Bedrock*** – No minimum separation distance is needed if filter is fully enclosed (i.e., no exfiltration). A separation distance of at least 3 feet is REQUIRED under the state CGP between the bottom elevation of vegetative filters and the elevation of the seasonally high water table (does not apply to wet swales).
- ***Site Location/Minimum Setbacks*** – A minimum setback of 50' between a stormwater pond and a water supply well is REQUIRED by the Minnesota Department of Health Rule 4725.4350. For purposes of this guidance, it is assumed that the definition of a stormwater pond includes a stormwater filtration system.

Conveyance

It is HIGHLY RECOMMENDED that a flow splitter or diversion structure be provided to divert the 5-year volume control standard **(VCS)** to media filters and allow larger flows to bypass the practice. Where a flow splitter is not used, it is HIGHLY RECOMMENDED that contributing drainage areas be limited to approximately 0.5 acres and an overflow be provided within the practice to pass part of the **VCS** to a stabilized watercourse or storm drain. It is HIGHLY RECOMMENDED that the flow splitter be designed such that 75% of the **VCS** can enter the treatment system prior to flow bypass occurring at the flow splitter. The overflow weir between the sedimentation and filtration chambers may be adjusted to be lower in elevation than the flow splitter weir to minimize bypass of the filter system prior to inflow filling the 75% **VCS** storage.

It is HIGHLY RECOMMENDED that media filters be equipped with a minimum 8" diameter underdrain in a 1' gravel bed. Increasing the diameter of the underdrain makes freezing less likely. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also HIGHLY RECOMMENDED that a permeable filter fabric be placed between the underdrain and gravel layer but not extend laterally from the pipe more than two feet on either side.

Pretreatment

Filtration is envisioned as a pretreatment device in the Northwest Area. If filtration becomes the primary device, the following shall be taken into consideration:

- Dry or wet pretreatment is REQUIRED prior to media filter treatment (pretreatment volume equivalent to at least 25% of the computed **VCS** is HIGHLY RECOMMENDED). The typical method is a sedimentation basin with a RECOMMENDED minimum length to width ratio of 2:1. The Camp-Hazen equation is used to compute the target surface area for media filters requiring full sedimentation for pretreatment (WSDE, 1992).

- The RECOMMENDED pretreatment for vegetative filters is a level spreader that allows coarse sediment to settle and evenly distributes flow across the full width of the filter.

- The RECOMMENDED pretreatment for media / vegetative filters such as dry swales is to install plunge pools where concentrated flows enter and to place level spreaders where lateral flows enter.

- Additional pretreatment measures include filter strips and street / parking lot sweeping. Street / parking lot sweeping may be considered pretreatment in the case of a parking lot island or other area where spatial limitations make structural pretreatment measures unfeasible.

- When using media filters to treat PSHs, particularly in sensitive watersheds, it is HIGHLY RECOMMENDED that additional practices be incorporated as partial treatment during the winter when the filter bed may be frozen.

Treatment

The following guidelines are applicable to the actual treatment area of a filtration facility:

- ***Space Required*** – Function of available head at site for surface filters. Underground filters have little or no space requirements except for access.
- ***Practice Slope*** – The surface slope of media filters should be level to promote even distribution of flow throughout practice. It is HIGHLY RECOMMENDED that vegetative filters have a maximum slopes of 5% and a minimum slope of 1%.
- ***Depth*** – The RECOMMENDED elevation difference at a site from the inflow to the outflow is 4-6 feet for most sand filters, and 2-3 feet for perimeter filters.
- ***Groundwater Protection*** – Exfiltration of untreated PSH runoff into groundwater is PROHIBITED. At confirmed hotspots, it is REQUIRED that filtered runoff be directed to the existing storm drain system or surface receiving waters.
- ***Aesthetics*** – Vegetative filters can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces. Media filters are less conducive to site aesthetics, but surface media filters can be designed with turf cover crops if desired.

Landscaping

It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation (see Appendix B) prior to introduction of stormwater into a filtration practice.

Surface filters can have a grass cover to aid in pollutant adsorption. The grass should be capable of withstanding frequent periods of inundation and drought.

Safety

It is REQUIRED that underground media filters only be accessed by individuals with appropriate confined space entry training. No building structures should be constructed on top of underground filters.

It is HIGHLY RECOMMENDED that swale side slopes be set at 3:1 (h:v) or flatter.

It is HIGHLY RECOMMENDED that perimeter sand filter grates be sufficiently heavy that they cannot be removed easily.

Fencing may be desirable in surface sand filter designs with significant vertical walls for the sedimentation and/or filter chamber. Fencing can also protect the filter from vandalism and limit animal access.

If a BMP is located in an area greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930

Construction Details

- Underground Sand Filter
- Perimeter Sand Filter
- Dry Swales
- Wet Swales
- Outlet structure with drawdown valve
- Diversion
- Emergency Overflow

C. Construction Specifications

Given that the construction of infiltration practices incorporates techniques or steps which may be considered non-standard, it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
   - Installation prior to site disturbance
   - Catch basin/inlet protection
   - Use of BMP as temporary sedimentation basin

II. Excavation, Backfill and Grading
   - Timing of grading of filtration practices (relative to total site development)
   - Use of low-impact, earth moving equipment
   - Restoration in the event of sediment accumulation during construction of practice
   - Gravel backfill specifications
   - Gravel filter specifications
   - Filter fabric specifications
   - Observation well specifications (if necessary)

III. Native Plants, Planting and Transplanting (Plant Material Selection in Appendix B of the Manual)
- ► Site preparation of planting areas
- ► Timing of native seeding and native planting
- ► Weed control
- ► Watering of plant material

IV. Construction Sequence Scheduling
- ► Temporary construction access
- ► Location of silt fence installation to protect BMPs and downgradient receiving waters
- ► Removal and storage of excavated material
- ► Installation of underground utilities
- ► Rough grading
- ► Seeding and mulching disturbed areas
- ► Road construction
- ► Final grading
- ► Site stabilization
- ► Installation of semi-permanent and permanent erosion control measures
- ► Silt fence removal

V. Construction Observation
- ► Adherence to construction documents
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately

Table 8.17 Sand Material Specifications

Parameter	Specification	Size	Notes
Sand	clean AASHTO M-6 or ASTM C-33 concrete sand	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. Rock dust cannot be substituted for sand.
Underdrain Gravel	AASHTO M-43	1.5" to 3.5"	
Geotextile Fabric (if required)	ASTM D-4833 (puncture strength - 125 lb.) ASTM D-1117 (Mullen Burst Strength - 400 psi) ASTM D-4632 (Tensile Strength - 300 lb.)	0.08" thick equivalent opening size of #80 sieve	Must maintain 125 gpm per sq. ft. flow rate. Note: a 4" pea gravel layer may be substituted for geotextiles meant to separate sand filter layers.
Impermeable Liner (if required)	ASTM D-4833 (thickness) ASTM D-412 (tensile strength 1,100 lb., elongation 200%) ASTM D-624 (Tear resistance - 150 lb./in) ASTM D-471 (water adsorption: +8 to -2% mass)	30 mil thickness	Liner to be ultraviolet resistant. A geotextile fabric should be used to protect the liner from puncture.
Underdrain Piping	ASTM D-1785 or AASHTO M-278	8" rigid schedule 40 PVC	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
Concrete (Cast-in-place)	See local Standards and Specs. f'c = 3,500 psi, normal weight, air-entrained; re-enforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.
Concrete (pre-cast)	per pre-cast manufacturer	n/a	SEE NOTE ABOVE
non-rebar steel	ASTM A-36	n/a	structural steel to be hot-dipped galvanized ASTM A-123

Source: Adapted from Vermont Stormwater Manual prepared by CWP

Table 8.18. Open Vegetated Swale and Filter Strip Materials Specifications			
Parameter	**Specification**	**Size**	**Notes**
Dry swale soil	USCS; ML, SM, SC	n/a	soil with a higher percent organic content is preferred
Dry Swale sand	ASTM C-33 fine aggregate concrete sand	0.02” to 0.04”	
Check Dam (pressure treated)	AWPA Standard C6	6” by 6” or 8” by 8”	*Do not* coat with creosote; embed at least 3’ into side slopes
Check Dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6” to 12” diameter; notch as necessary	*Do not* use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
Filter Strip sand/ gravel pervious berm	sand: per dry swale sand gravel; AASHTO M-43	sand: 0.02” to 0.04” gravel: 1/2” to 1”	Mix with approximately 25% loam soil to support grass cover crop; see Bioretention planting soil notes for more detail.
Pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8” to 3/8”)	Use clean bank-run gravel
Underdrain gravel	AASHTO M-43	1.5” to 3.5”	
Underdrain	ASTM D-1785 or AASHTO M-278	6” rigid Schedule 40 PVC	3/8” perf. @ 6” o.c.; 4 holes per row
Geotextile	See local Standards and Specs	n/a	
Rip rap	per local criteria	size per requirements based on 10-year design flows	

Source: Adapted from Vermont Stormwater Manual prepared by CWP

D. Operation and Maintenance

Overview

The most frequently cited maintenance concern for filters is surface and underdrain clogging caused by organic matter, fine silts, hydrocarbons, and algal matter. Common operational problems include:

- standing water
- clogged filter surface
- clogged, inlet, outlet or underdrains

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements of filtering systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include: limiting drainage area, providing easy site access (REQUIRED), and providing adequate pretreatment (REQUIRED).

Construction Phase Maintenance

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M). In particular, with filter construction the most important action for preventing operation and maintenance difficulties is to ensure that the contributing drainage area has been fully stabilized prior to bringing the practice on line (this is a REQUIRED practice).

Inspections during construction are needed to ensure the filter practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to verify the contractor's interpretation of the plan is acceptable with the designer. An example construction phase inspection checklist is provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of filtration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D.

- A site specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater filtration practice into operation:
  - Operating instructions for drawdown valves, gates and removable weirs (surface filters only)
  - Vegetation maintenance schedule
  - Inspection checklists
  - Routine maintenance checklists

- A legally binding and enforceable maintenance agreement should be executed between the facility owner and the local review authority to ensure the following:
  - Sediment should be cleaned out of the sedimentation chamber when it accumulates to a depth of more than six inches. The sediment chamber outlet devices should be cleaned/repaired when drawdown times exceed 72 hours (48 hours if its being used to meet MPCA requirements). Trash and debris should be removed as necessary.
  - Silt/sediment should be removed from the filter bed when the accumulation exceeds one inch. When the filtering capacity of the filter diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 72 hours), the top few inches of discolored material should be removed and replaced with fresh material. The removed sediments should be disposed in an acceptable manner (i.e., landfill).

- Media filters that have a grass cover should be mowed as needed during the growing season to maintain maximum grass heights less than 12 inches.

Table 8.19 Recommended Maintenance Activities for Media Filters	
Activity	**Schedule**
► If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of media, roto-till or otherwise cultivate the surface, and replace media with like material meeting the design specifications. ► Replace any filter fabric that has become clogged.	As needed
► Ensure that contributing area, facility, inlets and outlets are clear of debris. ► Ensure that the contributing area is stabilized and mowed, with clippings removed. ► Remove trash and debris. ► Check to ensure that the filter surface is not clogging (also check after storms greater than about 1”). ► Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. ► If permanent water level is present in pretreatment chamber (e.g., perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
► Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 6 inches of sediment. Remove sediment as necessary. ► Make sure that there is no evidence of deterioration, spalling or cracking of concrete. ► Inspect grates (perimeter sand filter). ► Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. ► Repair or replace any damaged structural parts. ► Stabilize any eroded areas. ► Ensure that flow is not bypassing the facility. ► Ensure that no noticeable odors are detected outside the facility.	Annually
► Remove and replace the top 2-5 inches of media every 3 to 5 years for low sediment applications, more often for areas of high sediment yield or high oil and grease.	3 to 5 years

Source: WMI, 1997, Pitt, 1997

Construction and Maintenance Costs

Table 8.20 is a list of the general components used in construction of this practice. Utilizing Table 8.20 will allow designers to avoid over or under estimation of fixed costs.

Table 8.20 Filtration Cost Components			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	X-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Underdrains	Underdrain cost ($/lineal foot) x length of device	Pipes, catchbasins, manholes, valves, vaults
	Vault structure (for media filters)	($/structure)	
	Media (for media filters)	Media cost ($/cubic yard) x filter volume (cubic yard)	
	Inlet structure (for vegetative filters	($/structure)	
	Outlet structure (for vegetative filters)	($/structure)	
Site Restoration	Filter strip	Sod cost ($/square foot) x filter strip area	Tree protection, soil amendments, seed bed preparation, trails
	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2x / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing (for some vegetative filters)	Mowing Cost ($) x Mowing Frequency (4x / 1 yr)	

Designers are encouraged to use the cost worksheet included in Appendix F to estimate their BMP construction cost.

Design Procedure: Media Filters

The following steps outline a recommended design procedure for media filters in compliance with the Inver Grove Heights stormwater permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a surface or perimeter sand filter, and identify the function of the filter in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks

B. Determine how the media filter will fit into the overall stormwater treatment system

- ► Decide whether the filter is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the media filter is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with Inver Grove Heights, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the media filter must comply with the MPCA construction general permit.

Step 3. Compute 5-year volume control standard and permanent pool volume.

Calculate the treatment volume per the standard (VCS).

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 4. Select design variant based on Physical Suitability Evaluation

Once the Physical Suitability Evaluation is complete, apply the Better Site Design principles in sizing and locating the filtration practice(s) on the development site. Given the drainage area, select the appropriate filtration practice for the first iteration of the design process.

Note: Information collected during the Physical Suitability Evaluation (see Step 2) should be used to explore the potential for multiple filtration practices versus relying on a single facility. The use of smaller filtration practices dispersed throughout development is usually more sustainable than a single regional facility that is more likely to have maintenance problems (Source: Wisconsin Department of Natural Resources Conservation Practice Standards 2004).

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the **VCS** to the sand filter facility.

Size low flow orifice, weir, or other device to pass $\mathbf{Q_{wq}}$.

Step 6. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

Af = (VCS) (df) / [(k) (hf + df) (tf)]

Where:

Af = surface area of filter bed (ft^2)
VCS = **Volume Control Standard**
df = filter bed depth (typically 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
hf = average height of water above filter bed (ft) (Typically 1/2 **hmax**, where **hmax** is the maximum head on the filter media and is typically ≤6 feet)
tf = design filter bed drain time (days) (3 days or 72 hours is required maximum)

Set preliminary dimensions of filtration basin chamber. The following guidelines are HIGHLY RECOMMENDED:

- The filter media should consist of an 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand) on top of the underdrain system.
- For surface sand filters, three inches of topsoil are placed over the sand bed. Permeable filter fabric is placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system.
- The filter bed is equipped with an 8-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum slope of 1%. Holes should be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
- Underground sand beds should be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed. The screen is to be rolled up, removed, cleaned and re-installed during maintenance operations.

Step 7. Size sedimentation chamber

Sedimentation chamber size is dictated by volume requirements, maximum ponding depth, and the particle settling ability. It is HIGHLY RECOMMENDED that the sedimentation chamber be sized to at least 25% of the computed **VCS** for surface sand filters and 50% for perimeter sand filters and have a length-to-width ratio of 2:1. It is REQUIRED that the depth of settling basins be in the range of 3' to 10' ($\mathbf{D_{max}}$), although site-specific requirements may apply. The Camp-Hazen equation is used to compute the surface area based on particle settling:

As = – (Qo/w) * Ln (1-E)

Where:

As = sedimentation basin surface area (ft^2)
Qo = rate of outflow = the **VCS** over a 24-hour period
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness <75%
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥75%
- average of 24 hour holding period

Then the equation reduces to:

As = (0.066) (VCS) ft2 for I < 75%

Or

As = (0.0081) (VCS) ft2 for I ≥ 75%

Use the following charts to set the preliminary surface area of settling chamber. Select the type of filter, imperviousness of the drainage area, and maximum ponding depth,

Sand Filter		Maximum Ponding Depth (feet)	
		<4	4 to 10
Imperviousness	≥75%	(0.25*VCS)/Dmax	(0.25*VCS)/Dmax
	<75%	(0.25*VCS)/Dmax	0.066*VCS

Perimeter Sand Filter		Maximum Ponding Depth (feet)	
		<7.5	8 to 10
Imperviousness	≥75%	(0.5*VCS)/Dmax	(0.5*VCS)/Dmax
	<75%	(0.5*VCS)/Dmax	0.066*VCS

Step 8. Compute V_{min} (minimum volume that can be stored within the filtration chamber)

V_{min} = 0.75 * VCS

Step 9. Compute storage volumes within entire facility and sedimentation chamber orifice size

***Surface sand filter*:**

V_{min} = 0.75 VCS = Vs + Vf + Vf_{temp}

(a) Compute **Vf** = water volume within filter bed/gravel/pipe = **Af * d_f * n**
Where: **n** = porosity = 0.4 for most applications

(b) Compute **Vf_{temp}** = temporary storage volume above the filter bed = **2 * hf * Af**

(c) Compute **Vs** = volume within sediment chamber = **V_{min} - Vf - Vf_{temp}**

(d) Compute **hs** = height in sedimentation chamber **= Vs/As**

(e) Ensure **hs** and **hf** fit available head and other dimensions still fit – change as necessary in design

iterations until all site dimensions fit.

(f) Size orifice from sediment chamber to filter chamber to release **Vs** within 24-hours at average release rate with 0.5 **hs** as average head.

(g) Design outlet structure with perforations allowing for a safety factor of 10.

***Perimeter sand filter*:**

(a) Compute **Vf** = water volume within filter bed/gravel/pipe = **Af** * **df** * **n**
Where: **n** = porosity = 0.4 for most applications

(b) Compute **Vw** = wet pool storage volume **As** * 2 feet minimum

(c) Compute $\mathbf{Vf}_{temp}$ = temporary storage volume = $\mathbf{V}_{min}$ – (**Vf** + **Vw**)

(d) Compute = $\mathbf{h}_{temp}$ = temporary storage height = $\mathbf{Vf}_{temp}$ / (**Af** + **As**)

(e) Ensure $\mathbf{h}_{temp} \geq \mathbf{2} * \mathbf{hf}$, otherwise decrease **hf** and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.

(f) Size distribution slots from sediment chamber to filter chamber.

Step 10. Design inlets, pretreatment facilities, underdrain system, and outlet structures

(a) Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber. Inlets to surface sand filters are to be provided with energy dissipaters. Exit velocities from the sedimentation chamber must be nonerosive.

(b) Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).

(c) An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

(d) Inlets to surface sand filters are to be provided with energy dissipaters. Exit velocities from the sedimentation chamber must be nonerosive.

The allowable materials for sand filter construction are detailed in Table 8.17.

Step 11. Compute overflow weir sizes

***Surface sand filter*:**

(a) Plan inlet protection for overflow from sedimentation chamber.

(b) Size overflow weir at elevation in filtration chamber above perforated stand pipe to handle surcharge of flow through filter system from 10-year storm.

Perimeter sand filter:

Size overflow weir at end of sedimentation chamber to handle excess inflow, set at VCS elevation.

Step 13. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps are iterative)

Follow the design procedures identified in chapter 7, Stormwater System Sizing, to determine the volume control standard.

Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site. This includes defining the parameters of the filtration practice defined above: pond elevation and area (defines the pond volume), filtration rate and method of application (effective filtration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated.

Period of Inundation

Filtration practices shall discharge through the soil or filter media in 72 hours or less. Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the filtration practice.

Design Procedure: Vegetative Filters (Adapted from the Georgia Stormwater Management Manual)

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a vegetative filter, and identify the function of the filter in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Regional or local depth to groundwater and bedrock
  - *Dry Swale:* Bottom of facility to be above the seasonably high water table.
  - *Wet Swale:* The seasonally high water table may inundate the swale; but not above the design bottom of the channel
- ► Site Location/Minimum setbacks

B. Determine how the vegetative filter will fit into the overall stormwater treatment system

- ► Decide whether the filter is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the vegetative filter is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with Inver Grove Heights, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the vegetative filter must comply with the MPCA Permit.

Step 3. Compute volume control standard

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 4. Select design variant based on physical suitability evaluation

Once the physical suitability evaluation is complete, it is HIGHLY RECOMMENDED that the Better Site Design principles be applied in sizing and locating the filtration practice(s) on the development site. Given the drainage area, select the appropriate filtration practice for the first iteration of the design process.

Note: Information collected during the physical suitability evaluation (see Step 1) should be used to explore the potential for multiple filtration practices versus relying on a single facility. The use of smaller filtration practices dispersed around a development is usually more sustainable that a single regional facility that is more likely to have maintenance problems (Source: Wisconsin Department of Natural Resources Conservation Practice Standards 2004

Step 5. Determine pretreatment method

Pretreatment

Pretreatment for vegetative filters is REQUIRED. It should consist of a level spreader that allows coarse sediment to settle and evenly distributes flow across the full width of the filter. Pretreatment should be provided with plunge pools where concentrated flows enter and with level spreaders where lateral flows enter.

Additional pretreatment measures include filter strips and street/parking lot sweeping. Street/parking lot sweeping may be considered pretreatment in the case of a parking lot island or other area where spatial limitations make structural pretreatment measures unfeasible.

Step 6. Preliminary design

Wet and Dry Swales:

a. Size bottom width, depth, length, and slope necessary to store **VCS** with less than 18 inches of ponding at the downstream end.

b. Slope cannot exceed 4% (1 to 2% recommended)

c. Bottom width should range from 2 to 8 feet

d. Ensure that side slopes are no greater than 3:1 (4:1 recommended)

The peak velocity for the 2-year storm must be nonerosive for the soil and vegetative cover provided.

The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Step 7. Compute number of check dams (swales) or berms (filter strip)

Wet and Dry Swales: Checkdams

If checkdams are used a reduction in VCS may be realized.

Channel slopes between 1% and 2% are recommended unless topography necessitates a steeper slope, in which case 6- to 12-inch drop structures can be placed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet. Depth of the **VCS** at the downstream end should not exceed 18 inches.

Step 8. Calculate draw-down time

Dry swale:

The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above an 8-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 12-inch gravel layer. The soil media should have an infiltration rate of at least 0.5 feet per day (fpd) with a maximum of 1.5 fpd and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil.

Step 9. Check 2-year and 10-year velocity erosion potential and freeboard

Check for erosive velocities and modify design as appropriate based on soils. Provide 6 inches of freeboard.

Step 10. Design low flow control at downstream headwalls and checkdams
Design control to pass **VCS** in 6 hours.

Step 11. Design inlets, sediment forebay(s), and underdrain system (dry swale)

Inlets to swales must be provided with energy dissipaters such as riprap or geotextile reinforcement. Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet. Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control. A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

The underdrain system should discharge to the storm drainage infrastructure or a stable outfall. For a wet swale, do not use an underdrain system.

Step 12. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps are iterative)
Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site. This includes defining the parameters of the filtration practice defined above: pond elevation and area (defines the pond volume), filtration rate and method of application (effective filtration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated.

Period of Inundation

Filtration practices shall discharge through the soil or filter media in 72 hours or less. Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized

discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the filtration practice.

Step 13. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation. The recommended construction materials for open channels and filter strips are detailed in Table 8.18. Further information on plant selection and use occurs in Appendix B of the manual.

Landscape design should specify proper grass species and wetland plants based on specific site, soils and hydric conditions present along the channel.

E. References

Design Hydrology and Sedimentology for Small Catchments. 1994. Haan, C.T., Barfield, B.J., Hayes, J.C.

Design of Stormwater Filtering Systems. 1996. Center for Watershed Protection.

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual, Stormwater Best Management Practice for Cold Climates*. St. Paul, MN.

Vermont Stormwater Management Manual. 2002. http://www.vtwaterquality.org/stormwater.htm.

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BIORETENTION



Raingarden in a commercial development - Stillwater, MN

Definition:
Bioretention is a terrestrial-based (upland as opposed to wetland), water quality and water quantity control process. Bioretention employs a simplistic, site integrated design that provides opportunity for runoff infiltration, filtration, storage and water uptake by vegetation.

KEY CONSIDERATIONS

Design Criteria:

- Infiltration requires suitable soils.
- Minimum 10' setback and located down grade from home foundations.
- Best applied to drainage areas with relatively flat slopes (5%).

Benefits:

- Can be very effective for removing fine sediment, trace metals, nutrients, bacteria and organics (Davis *et al*. 1998).
- Provides many additional environmental (*habitat, improves air quality, urban micro-climates*), social (*creates a unique sense of place*) and economic benefits (*reduces development and maintenance cost, greater lot yield, increases property values*).
- Well suited for high impervious areas.
- Reduces runoff volume.
- Flexible design, affording many opportunities for creativity.

Limitations:

- Susceptible to clogging by sediment; therefore maintenance and pre-treatment is necessary to maintain effectiveness.
- Not effective for large drainage areas (use multiple structures, closer to source of runoff).
- Space consumption (5%-10% of drainage area).

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X*	Infiltration *with appropriate soils & site conditions
X	Filtration
X	Temperature Control
X	Settling
	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

85%	Total Suspended Solids
65%/ 50%	Nutrients - Total Phosphorus/ Total Nitrogen
95%	Metals - Cadmium, Copper, Lead, and Zinc
35%*	Pathogens - Coliform, Streptococci, E. Coli *less than 5 independent studies
80%*	Toxins - Chloride, Hydrocarbon, Pesticide *less than 5 independent studies

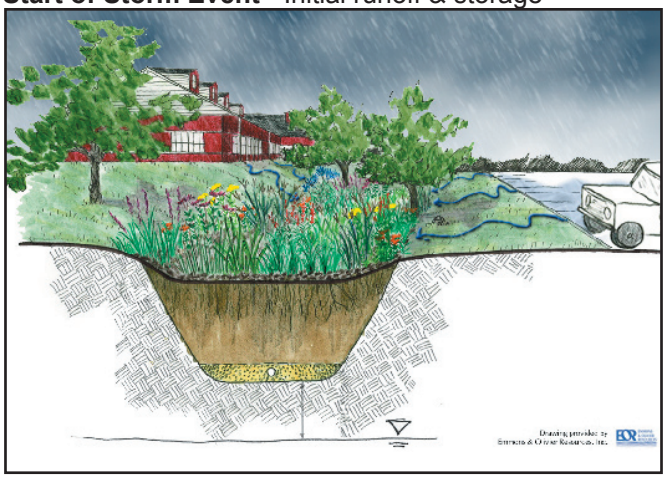
Note: Average pollutant removal expected when sizing based on MPCA criteria. Values apply to treated runoff only.

SITE FACTORS

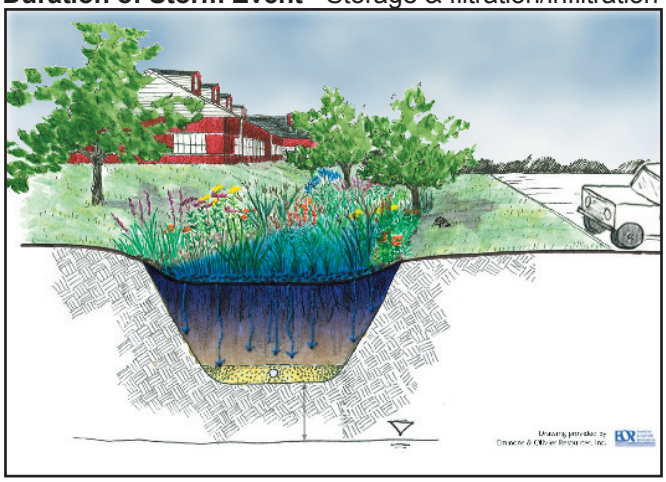
2 AC Max; 1 AC Max Impervious	Drainage Area For Filtration Design (Per Practice)
2 AC Max; 1/2 AC Max Impervious	Drainage Area For Infiltration Design (Per Practice)
20%	Max. Slope of Site
3'	Min. Depth to Bedrock & Seasonally High Water Table
A,B - Normal	NRCS Soil Type *can be used in C&D soil types with modifications (e.g. under-drains)
Good	Freeze/ Thaw Suitability
Suitable	Potential Hotspot Runoff *requires impermeable liner

STORM SEQUENCE

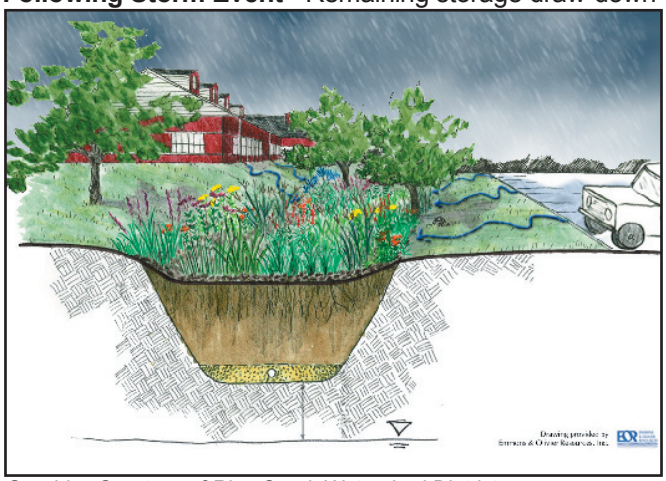
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Graphics Courtesy of Rice Creek Watershed District

Description:

In general, bioretention systems can be described as shallow, landscaped depressions commonly located in parking lot islands or within small pockets in residential areas that receive stormwater runoff (Metropolitan Council Small Sites BMP Manual, 2001).

Bioretention facilities capture rainwater runoff to be filtered through a prepared soil medium. Once the soil pore space capacity of the medium is exceeded, stormwater begins to pool at the surface of the planting soil. Pollutants are removed by a number of processes including adsorption, filtration, volatilization, ion exchange and decomposition (Prince George's County, MD, 1993). Filtered runoff can either be allowed to infiltrate into the surrounding soil (functioning as an infiltration basin or rainwater garden), or collected by an under-drain system and discharged to the storm sewer system or directly to receiving waters (functioning like a surface sand filter). Runoff from larger storms is generally diverted past the area to the storm drain system (Metropolitan Council Small Sites BMP Manual, 2001).

Bioretention is a stormwater treatment practice that utilizes the chemical, biological and physical properties of plants, microbes and soils for capturing/ reducing stormwater runoff and removing pollutants from runoff. This process is often incorporated into many different types of filtration and infiltration stormwater treatment practices.

A. Suitability

General

Bioretention areas are suitable stormwater treatment practices for all land uses, as long as the contributing drainage area is appropriate for the size of the facility. Common bioretention opportunities include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, and street-scapes (i.e., between the curb and sidewalk). Bioretention, when designed with an underdrain and liner, is also a good design option for treating potential stormwater hotspots (PSHs). Bioretention is extremely versatile because of its ability to be incorporated into landscaped areas. The versatility of the practice also allows for bioretention areas to be frequently employed as stormwater retrofits.

Function Within Stormwater Treatment Train

Unlike end-of-pipe BMPs, bioretention facilities are typically shallow depressions located in upland areas. The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable subwatersheds, and thus, will help in controlling runoff close to the source where it is generated (Prince George's County Bioretention Manual, 2002).

Bioretention facilities are designed to function by essentially mimicking certain physical, chemical, and biological processes that occur in the natural environment. Depending upon the design of a facility, different processes can be maximized or minimized depending on the type of pollutant loading expected (Prince George's County Bioretention Manual – 2002).

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Bioretention systems that incorporate infiltration may reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Small-scale bioretention areas are expected to make up a large portion of the 5-year 24-hour infiltration standard. Bioretention devices may also be used to meet the Inver Grove Heights pretreatment requirements. (Chapter 6)

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Alternative Names

As bioretention becomes a more common tool in the stormwater management toolbox and as the number of design variants increases, so does the number of names for each of these variants.

As an example of the ongoing evolution of bioretention terminology, the terms “Raingarden” and “Rainwater Garden” have recently caught on with the public and are being used interchangeably with Bioretention. In most instances, Raingarden designs are utilizing the processes of bioretention, but the term Raingarden is also being loosely used to describe BMPs that are operating more as stormwater ponds (or as other BMPs) than as bioretention facilities.

Further confusion stems from using the terms “process” and “practice” interchangeably. As mentioned earlier, bioretention is not a “practice” per se but rather a process or group of processes that can be incorporated into many different practices.

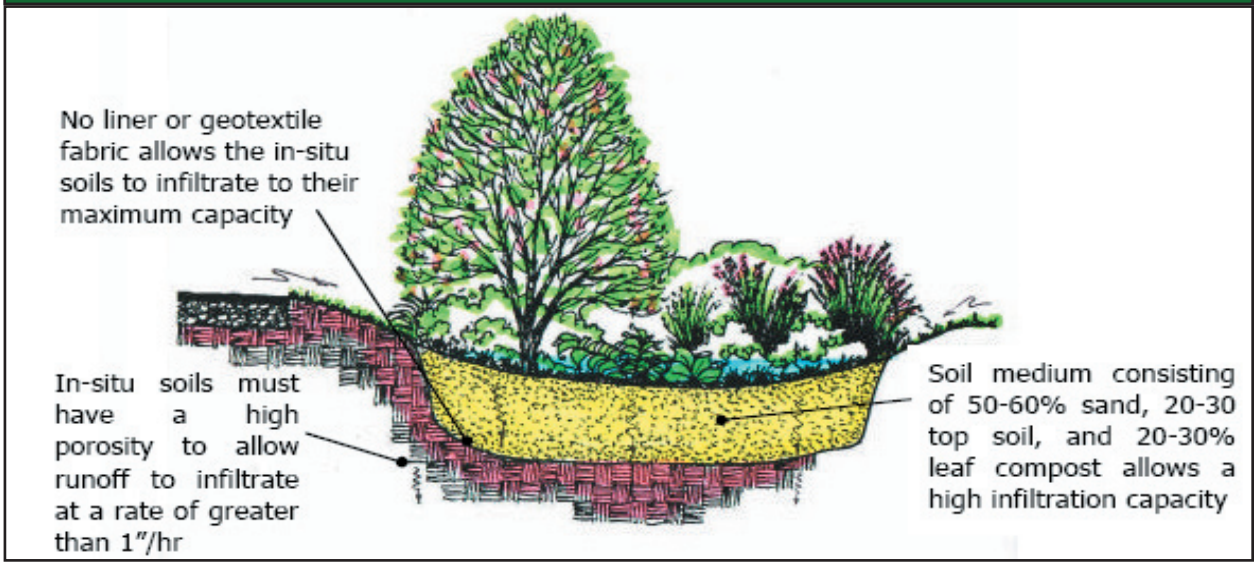
This section of is provided to clarify the more common bioretention terminology being used in the field of stormwater management today.

Performance Types (adapted from Prince George’s County 2002)

The following facility performance types have been slightly modified for Minnesota to optimize the expected or anticipated pollutant loadings based on the proposed land use. All of these facilities may be used as high-hydraulic-capacity filtration systems. High-hydraulic-capacity filtration systems are defined as systems that are composed of essentially a shallow sandy soil mix, thick layer of mulch and an underdrain/gravel discharge system.

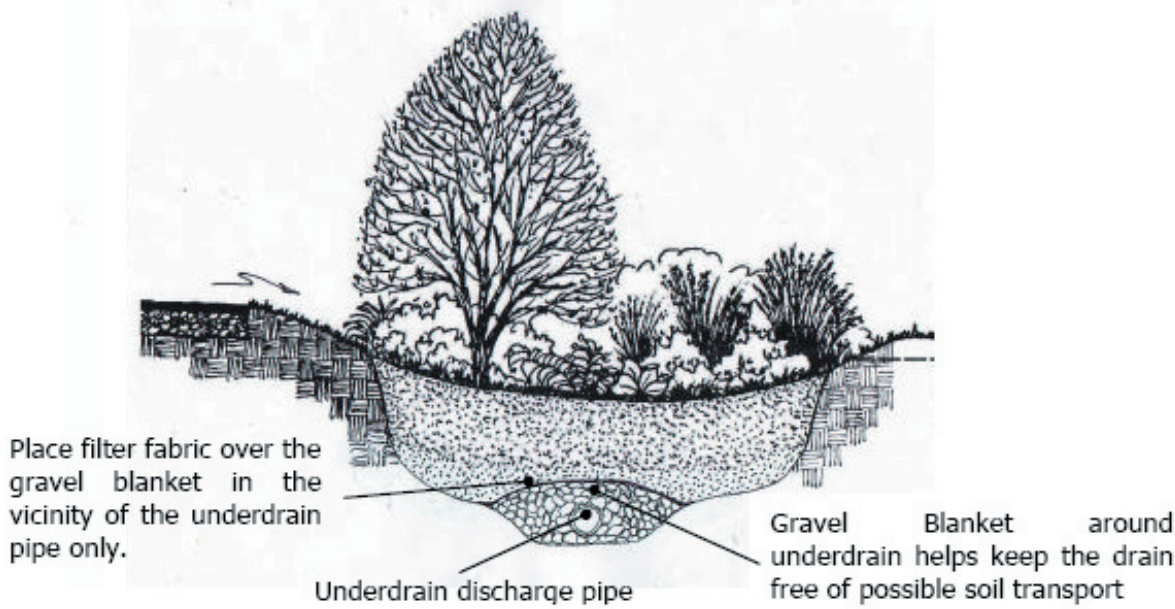
- ***Infiltration / Recharge Facility*** **-** This type of facility is suitable for areas where high recharge of groundwater would be beneficial. Because there is no underdrain, the in-situ soils need to have a high infiltration rate to accommodate the inflow levels. The infiltration rate of the in-situ soils must be determined through proper soil testing/diagnostics. Preferably, facilities of this type should have infiltration rates of 1”/hr or greater. Facilities must be at least 2.5 feet deep to allow adequate filtration processes to occur. Siting of these facilities should be in areas where visibility is not a concern because hydraulic overload can cause extended periods of standing water conditions. This facility type is suitable for areas and land uses that are expected to generate nutrient runoff (i.e.; residential and business campuses) that can be infiltrated and captured by the facility. Fresh mulch rather then aged shredded bark mulch can be used to enhance denitrification processes.

Figure 8.5 Infiltration / Recharge Facility



Source: Prince George’s County Bioretention Manual - 2002

Figure 8.6 Filtration/Partial Recharge Facility

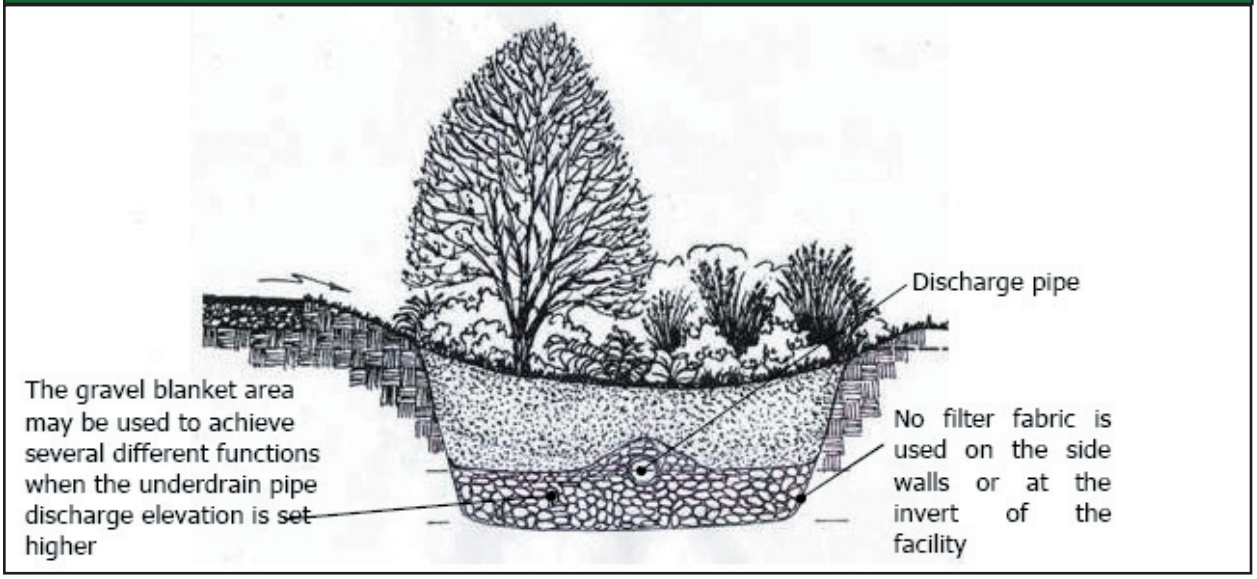


Source: Prince George's County Bioretention Manual - 2002

- ***Filtration/Partial Recharge Facility –*** This type of facility is suitable for areas where high filtration and partial recharge of runoff would be beneficial. This facility is designed with an underdrain at the invert of the planting soil mix to ensure that the facility drains at a desired rate. The facility allows for partial recharge, as an impervious liner is not used. The depth is also shallow (2.5') to allow the facility to handle high capacity flows if necessary. Siting of this performance type is suitable for visually prominent or gateway locations in a community. The facility type is suitable for areas and land uses that are expected to generate nutrient and metals loadings (residential, business campus, or parking lots). Attention to mulch type and amount will ensure the adequate treatment of the anticipated loadings. The facility shown in Figure 8.6 incorporates a filter material between the gravel blanket around the underdrain and the planting soil above. The filter fabric does not need to extend to the side walls. The filter fabric may be installed horizontally above the gravel blanket- extending just 1-2 feet on either side of the underdrain pipe below. Do ***not*** wrap the underdrain with filter fabric. Instead of using a filter fabric, the designer may opt to utilize a pea gravel diaphragm over the underdrain gravel blanket. This type of facility is also recommended for tight impermeable soils where infiltration is limited. Some volume reduction will be seen from evapotranspiration.

- ***Infiltration/Filtration/Recharge*** – This type of facility is recommended for areas where higher nutrient loadings (particularly nitrates) are anticipated. The facility is designed to incorporate a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe. This fluctuation created by saturation and infiltration into the surrounding soils will achieve de-nitrification. With a combination of a fresh mulch covering, nitrates will be mitigated through the enhancement of natural denitrification processes. This type of facility would be suitable for areas where nitrate loadings are typically a problem (residential communities). The raised underdrain has the effect of providing a storage area below the invert of the underdrain discharge pipe. This area provides a recharge zone and quantity control can also be augmented with this storage area. The storage area is equal the void space of the material used.

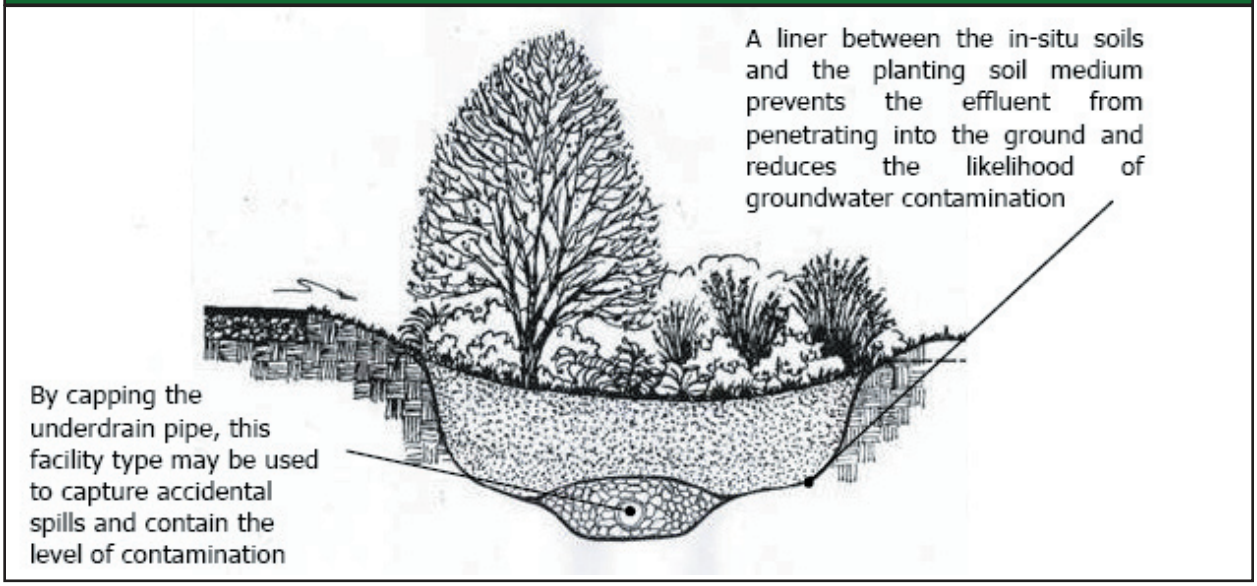
Figure 8.7 Infiltration/Filtration/Recharge Facility



Source: Prince George's County Bioretention Manual - 2002

Filtration Only – This type of facility is recommended for areas that are known as "hot-spots" (gas stations, transfer sites, and transportation depots). An important feature of this type of facility is the impervious liner designed to reduce or eliminate the possibility of groundwater contamination. The facility provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point. In the event of an accidental spill, the underdrain can be blocked and the objectionable materials siphoned through the observation well and safely contained.

Figure 8.8 Filtration Only Facility



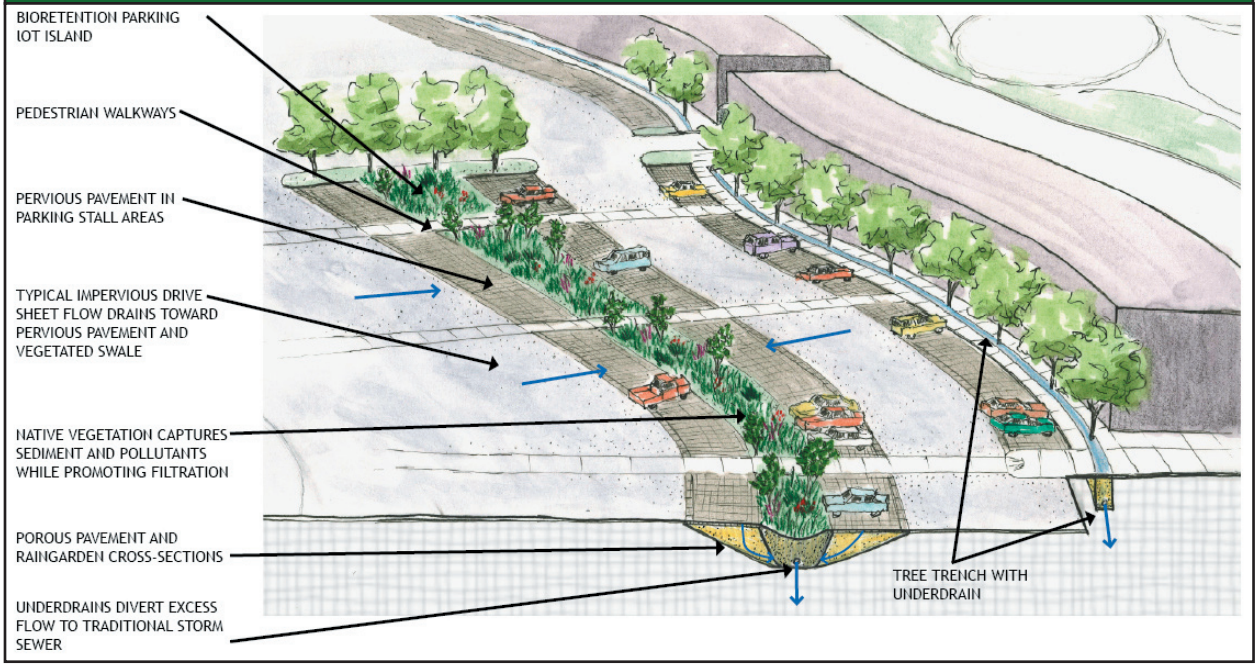
Source: Prince George's County Bioretention Manual - 2002

Design Types for Various Land Uses

It should be noted that the layout of the bioretention area will vary according to individual sites, and to specific site constraints such as underlying soils, existing vegetation, drainage, location of utilities, sight distances for traffic, and aesthetics. Designers are encouraged to be creative in determining how to integrate bioretention into their respective site designs. With this in mind, the following conceptual illustrations are presented as alternative options.

- ***On-lot / Raingarden –*** Simple design that incorporates a planting bed in the low portion of the site. On-lot systems are designed to receive flows from gutters, and/or other impervious surfaces.
- ***Parking Lot Islands (Curbless)*** – In a paved area with no curb, pre-cast car stops or a "ribbon curb" can be installed along the pavement perimeter to protect the bioretention area. This application of bioretention should only be attempted where shallow grades allow for sheet flow conditions over level entrance areas. Water may be pooled into the parking area where parking spaces are rarely used, to achieve an element of stormwater quantity control beyond the confines of the bioretention surface area (Prince George's County 2002).
- ***Parking Lot Islands (Curb cut)*** – For curb-cut entrance approaches, the water is diverted into the bioretention area through the use of an inlet deflector block, which has ridges that channel the runoff into the bioretention area (Prince George's County 2002). Special attention to erosion control and pretreatment should be given to the concentrated flow produced by curb cuts. Figure 8.9 features a parking lot island bioretention facility in context with other stormwater BMPs.

Figure 8.9 Parking Lot Island Bioretention Facility



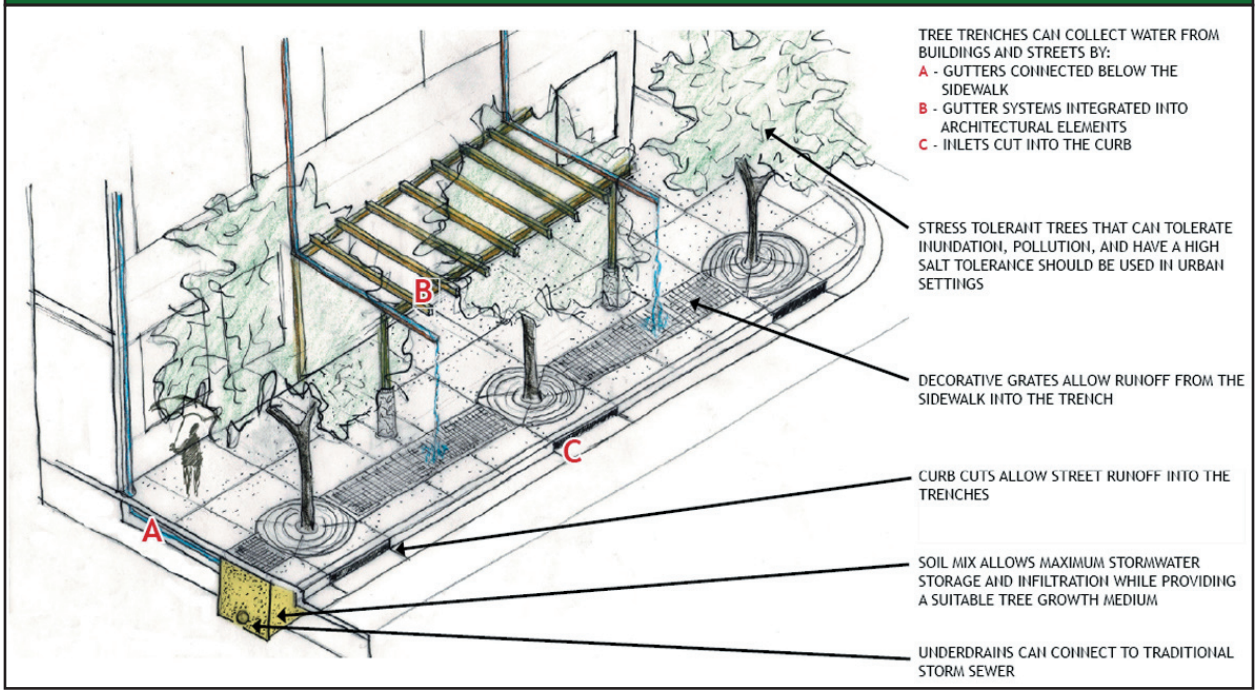
- ***Road Medians / Traffic Islands –*** Create a multifunctional landscape by utilizing road medians and islands for bioretention. There is no minimum width recommended for traffic islands from street edge to edge. A buffer may be necessary along the outside curb perimeter to minimize the possibility of drainage seeping under the pavement section, and creating "frost heave" during winter months. Alternately, the installation of a geotextile filter fabric "curtain wall" along the perimeter of the bioretention island will accomplish the same effect.

► ***Tree Pits / Tree Box Filters –*** Tree Pits and Tree Box Filters afford many opportunities for bioretention. Designs vary widely from simple "tree pits", used for local drainage interception to more formal Tree Box Filters, which are a useful tool for highly urbanized streetscapes.

The Tree Pit technique provides very shallow ponding storage areas in a "dished" mulch area around the tree or shrub. Typically, the mulched area extends to the dripline for the tree and is similar to conventional mulching practices, except that the mulch area is depressed at least 2-3" rather than mounded around the tree (Low Impact Development Center – 2005).

Tree Box Filters are bioretention areas installed beneath trees that can be very effective at controlling runoff, especially when distributed throughout the site. Runoff is directed to the tree box, where it is cleaned by vegetation and soil before entering a catch basin. The runoff collected in the tree-boxes helps irrigate the trees. The system consists of a container filled with a soil mixture, a mulch layer, under-drain system and a shrub or tree. Stormwater runoff drains directly from impervious surfaces through a filter media. Treated water flows out of the system through an under drain connected to a storm drainpipe / inlet or into the surrounding soil. Tree box filters can also be used to control runoff volumes / flows by adding storage volume beneath the filter box with an outlet control device (Low Impact Development Center – 2005). Figure 8.10 details a Tree Box Filters in a chain.

Figure 8.10 Tree Box Filteres



Retrofit Suitability

The ability to use bioretention as a retrofit often depends on the age of development within a subwatershed. Subwatersheds that have been developed over the last few decades often present many bioretention opportunities because of open spaces created by modern setback, screening and landscaping requirements in local zoning and building codes. However, not every open area will be a good candidate for bioretention due to limitations associated with existing inverts of the storm drain system and the need to tie the under drain from the bioretention area into the storm drain system. In general, four to six feet of elevation above this invert is needed to drive storm water through the proposed bioretention area.

Cold Climate Suitability

Little research exists on the cold climate effectiveness of bioretention devices. Some believe that bioretention can be of marginal effectiveness for treating snowmelt runoff because of the dormancy of the vegetation during the cold season. However, the incorporation of some sump storage into the design of any bioretention system will provide an opportunity to route and collect snowmelt runoff and begin the filtration and infiltration processes. The incorporation of some storage as part of the system (for example, setting the outlet elevation 6" to 12" above the bottom of the bioretention device) is necessary for this adaptation. Once relatively "warm" snowmelt runoff begins to accumulate in a bioretention system, some downward migration will likely begin and the system will activate. A system that is relatively dry when winter begins will respond more quickly and treat spring runoff more effectively once melt begins (see Chapter 6 for Cold Climate discussions).

Water Quantity Treatment

Bioretention practices are not typically suitable for providing complete water quantity control, but can be used to infiltrate a portion of the Inver Grove Heights Volume Control Standard (VCS). They are normally either designed off-line using a flow diversion or configured to safely pass large storm flows while still protecting the ponding area, mulch layer and vegetation. Experience and modeling analysis have shown that bioretention can be used for stormwater management quantity control when facilities are distributed throughout a site to reduce runoff and maintain the preexisting time of concentration. This effort can be incorporated into the site hydrologic analysis

Water Quality Treatment

Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms including vegetative filtering, settling, evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal and effluent concentration data for select parameters are provided in Tables 8.19 and 8.20, respectively. Bioretention can also be designed as an effective infiltration / recharge practice, particularly when parent soils have high permeability (> ~ 0.5 in/hr). Where soils are not favorable, a rock infiltration gallery can be used to promote slow infiltration / recharge of stored water.

Table 8.19 Percent Removal of Key Pollutants by Bioretention

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[2] [%]	Bacteria [%]	Hydro-carbons [%]
Bioretention1	85*	65	50	95	35*	80*

1. Based on fewer than five data points (i.e., independent monitoring studies)
2. Average of zinc and copper
* Assumed values based on filtering practice performance

Source: Winer, 2000

Table 8.20 Typical BMP Best Achievable Effluent Concentrations

Practice	TSS	TP	TN	Cu[1]	Zn[1]
Bioretention	11	0.3	1.1[2]	7	40

1. Units for Zn and Cu are micrograms per liter
* Assumed values based on filtering practice performance

Source: Winer, 2000

Early bioretention facilities were designed to provide water quality benefits by controlling the "first flush" event. Using highly permeable planting soils and an underdrain, however, creates a high-rate biofilter, which can treat 90-95% (or higher) of the total annual volume of rainfall/runoff. Furthermore, monitoring has shown the pollutant removal rates to be significantly above the estimates presented in the original manual (Prince George's County 2002).

Limitations

The following general limitations should be recognized when considering installation of a bioretention practice:

- Non traditional stormwater management technique;
- Maintenance personnel may need additional instruction on routine Operation and Maintenance requirements;
- Lack of long-term performance and operation and management information.

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a bioretention device for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. The following list of considerations will help in making an initial judgment as to whether or not a bioretention device is the appropriate BMP for the site.

- ***Drainage Area*** – 5 acres maximum RECOMMENDED (0.5 to 2 acres is ideal). For larger sites, multiple bioretention areas can be used to treat site runoff provided appropriate grading is present to convey flows.
- ***Site Topography and Slopes*** – It is RECOMMENDED that sloped areas immediately adjacent to the bioretention practice be less than 20% but greater than 1%, to promote positive flow towards the practice.
- ***Soils*** – No restrictions; engineered media HIGHLY RECOMMENDED; underdrain is HIGHLY RECOMMENDED where parent soils are HSG C or D.
- ***Depth to Groundwater and Bedrock*** – A separation distance of 3 feet is REQUIRED between the bottom of the bioretention facility and the elevation of the seasonally high water table or bedrock.
- ***Site Location/Minimum Setbacks*** – A minimum 10 foot separation from building foundations is REQUIRED, with slopes directed away from building.

Conveyance

It is HIGHLY RECOMMENDED that overflow associated with the 10- or 25-year storm (depending on local drainage criteria) be controlled such that velocities are non-erosive at the outlet point (to prevent downstream slope erosion), and that when discharge flows exceed 3 cfs, the designer evaluate the potential for erosion to stabilized areas and bioretention facilities.

Common overflow systems within the structure consist of a yard drain inlet, where the top of the yard drain inlet is placed at the elevation of the shallow ponding area. A stone drop of about twelve inches or small stilling basin could be provided at the inlet of bioretention areas where flow enters the practice through curb cuts or other concentrated flow inlets. In cases with significant drop in grade this erosion protection should be extended to the bottom of the facility.

It is HIGHLY RECOMMENDED that bioretention areas with underdrains be equipped with a minimum 8" diameter underdrain in a 1' deep gravel bed. Increasing the diameter of the underdrain makes freezing less likely, and provides a greater capacity to drain standing water from the filter. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also HIGHLY RECOMMENDED that a pea gravel diaphragm and/or permeable filter fabric be placed between the gravel layer and the filter media.

Pretreatment

Adequate pretreatment for bioretention systems is REQUIRED. It is HIGHLY RECOMMENDED that pretreatment incorporate as many of the following as are feasible:

- grass filter strip below a level spreader or grass channel
- gravel diaphragm
- a mulch layer.

If bioretention is used to treat runoff from a parking lot or roadway that is frequently sanded during snow events, there is a high potential for clogging from sand in runoff. It is HIGHLY RECOMMENDED that grass filter strips or grass channels at least 10 or 20 feet long, respectively, convey flow to the system in these situations. Local requirements may allow a street sweeping program as an acceptable pretreatment practice.

Treatment

The following guidelines are applicable to the actual treatment area of a bioretention facility:

- ***Space Required*** – It is RECOMMENDED that approximately 7-10% of the tributary impervious area be dedicated to the practice footprint; with a minimum 200 square foot area for small sites (equivalent to 10 feet x 20 feet)
- ***Practice Slope –*** It is RECOMMENDED that the slope of the surface of the bioretention practice not exceed 1%, to promote even distribution of flow throughout.
- ***Depth*** – It is RECOMMENDED that the elevation difference from the inflow to the outflow be approximately 4-6 feet when an underdrain is used.
- ***Groundwater Protection*** – Exfiltration of unfiltered PSH runoff into groundwater is prohibited.

It is HIGHLY RECOMMENDED that bioretention not be used on sites with a continuous flow from groundwater, sump pumps, or other sources. The following treatment design components for bioretention systems are also HIGHLY RECOMMENDED:

- 2.5 to 4 foot deep planting soil bed (i.e., "filter bed")
- surface mulch layer
- 6-18 inch deep surface ponding area
- surface ponding of up to 12 inches may be allowed in areas with shallow bedrock.

Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth. The bioretention area should be sized based on the principles of Darcy's Law. A coefficient of permeability k = 0.5 ft/day is appropriate to characterize the planting medium / filter media soil (Claytor and Schueler, 1996). This value is conservative to account for clogging associated with accumulated sediment.

It is REQUIRED that the design permeability rate through the planting soil bed be high enough to fully drain the stormwater quality design storm runoff volume within 72 hours (48 hours if its being used to meet MPCA requirements). It is HIGHLY RECOMMENDED that this permeability rate must be determined by field or laboratory testing.

When using bioretention to treat PSHs, particularly in sensitive watersheds, it is HIGHLY RECOMMENDED that additional practices be incorporated as a treatment train for at least limited treatment during the winter when the bioretention area may be frozen.

Landscaping

It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into a bioretention practice. Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan is REQUIRED for bioretention areas. RECOMMENDED planting guidelines for bioretention facilities are as follows:

- Vegetation should be selected based on a specified zone of hydric tolerance. *Plants for Stormwater Design* by the Minnesota Pollution Control Agency is a good resource.
- Native plant species should be specified over non-native species. Hardy native species that thrive in our ecosystem without chemical fertilizers and pesticides are the best choices.
- Many bioretention facilities feature wild flowers and grasses as well as shrubs and some trees.
- Woody vegetation should not be specified at inflow locations.
- Trees should not be planted directly overtop of underdrains and may be best located along the perimeter of the practice.
- Salt resistant vegetation should be used in locations with probable adjacent salt application, i.e. roadside, parking lot, etc.
- Fluctuating water levels following seeding (prior to germination) can cause seed to float and be transported. Seed is also difficult to establish through mulch, a common surface component of Bioretention. It may take up to two growing seasons to establish the function and desired aesthetic of mature vegetation via seeding. Therefore mature plantings are recommended over seed.
- If a minimum coverage of 50% is not achieved after the first growing season, a reinforcement planting is required
- Bioretention area locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design.

Safety

Bioretention practices do not pose any major safety hazards. Trees and the screening they provide may be the most significant consideration of a designer and landscape architect. Where inlets exist, they should have grates that either have locks or are sufficiently heavy that they cannot be removed easily. Standard inlets and grates used by Mn/DOT and local jurisdictions should be adequate. Fencing of bioretention facilities is generally not desirable

Construction Details

Soil Medium / Filter Media Content

A well blended, homogenous mixture of 50-60% construction sand: 20-30% top soil; and 20-30% organic leaf compost is necessary to provide a soil medium with a high infiltration/filtration capacity.

- ***Sand*** - AASHTO M-6 or ASTM C-33 with grain size of 0.02”- 0.04”
- ***Top Soil*** - sandy loam, loamy sand, or loam texture per USDA textural triangle with less than 5% maximum clay content
- ***Organic Leaf Compost*** - (MnDOT Grade 2)

Soil Medium / Filter Media Depth

Field experiments show that pollutant removal is accomplished within the top 30” of soil depth with minimal additional removal beyond that depth (Prince George’s County 2002). Therefore, the recommended depth

of the prepared soil is 30 inches. However, if large trees are preferred in the design, a soil depth of 48”-52” should be utilized. The soil depth generally depends upon the root depth of the prescribed vegetation and content of underlying soils.

Gravel Filter Specifications - Underdrain gravel blanket shall be double washed stone, 1-1/2” in size. Pea Gravel shall be washed, river-run, round diameter, ¼ - ½ in size.

Mulch Content and Depth - Fresh shredded bark mulch (Mn/DOT Type 6) should be used when possible to maximize nitrogen retention. If aged mulch is used, use the shredded type instead of the “chip” variety to minimize floating action. The mulch layer should not exceed 3” in depth. Too much mulch can restrict oxygen flow to roots. In addition, mulch should not be mounded around the base of plants since this encourages damage from pests and diseases.

C. Construction Specifications

Given that the construction of bioretention practices incorporates techniques or steps which may be considered non-traditional, it is recommended that the construction specifications include the following format and information.

I. Temporary Erosion Control
- ► Install prior to site disturbance
- ► Protect catch basin/inlet
- ► It is HIGHLY RECOMMENDED that future bioretention locations not be used as temporary sedimentation basins. If used as temporary sedimentation basins, the bioretention facility should be over excavated a minimum of 18” below sedimentation basin grade.

II. Excavation, Backfill and Grading
- ► Timing of grading of infiltration practices relative to total site development
- ► Use of low-impact, earth moving equipment
- ► Do not over-excavate
- ► Restoration in the event of sediment accumulation during construction of practice
- ► Gravel backfill specifications
- ► Gravel filter specifications
- ► Filter fabric specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix E of the Manual)
- ► Site preparation of planting areas
- ► Timing of native seeding and native planting
- ► Weed control
- ► Watering of plant material

IV. Construction Sequence Scheduling
- ► Temporary construction access
- ► Location of silt fence installation to protect BMPs and downstream receiving waters
- ► Removal and storage of excavated material
- ► Installation of underground utilities
- ► Rough grading
- ► Seeding and mulching disturbed areas
- ► Road construction
- ► Final grading
- ► Site stabilization
- ► Installation of semi-permanent and permanent erosion control measures
- ► Silt fence removal

V. Construction Observation
   - ► Adherence to construction documents
   - ► Verification of physical site conditions
   - ► Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

The most frequently cited maintenance concern for bioretention is surface and underdrain clogging caused by organic matter, fine silts, hydrocarbons, and algal matter. Common operational problems include:

- ► standing water
- ► clogged filter surface
- ► inlet, outlet or underdrains clogged

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements of bioretention systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include: limiting drainage area, providing easy site access (REQUIRED), providing pretreatment (REQUIRED), and utilizing native plantings.

Construction Phase Maintenance

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M). In particular, with construction of bioretention practices the most important action for preventing operation and maintenance difficulties is to ensure that the contributing drainage area has been fully stabilized prior to bringing the practice on line (this is a REQUIRED practice).

Inspections during construction are REQUIRED to ensure that the bioretention practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of bioretention practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix F.

- ► A site specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater filtration practice into operation:
    - Operating instructions for outlet component
    - Vegetation maintenance schedule
    - Inspection checklists
    - Routine maintenance checklists
- ► A legally binding and enforceable maintenance agreement should be executed between the practice owner and the City of Inver Grove Heights.

- ► Adequate access must be provided for all bioretention facilities for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.
- ► The surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of non-vegetated areas may be required to ensure adequate filtration.
- ► Bioretention areas should not be used as dedicated snow storage areas.
    - Areas designed for infiltration should be protected from excessive snow storage where sand and salt is applied
    - Specific soil storage areas should be assigned that will provide some filtration before the storm water reaches the infiltration areas.
    - When used for snow storage, or if used to treat parking lot runoff, the bioretention area should be planted with salt tolerant, and non-woody plant species

- ► Bioretention areas should always be inspected for sand build-up on the surface following the spring melt event.
- ► General maintenance activities and schedule are provided in Table 8.21.

Table 8.21 Recommended Maintenance Activities for Bioretention Areas

Activity	Schedule
► Pruning and weeding to maintain appearance. ► Mulch replacement when erosion is evident. ► Remove trash and debris. ► Mow filter strip.	As needed
► Inspect inflow points for clogging (off-line systems). Remove any sediment. ► Inspect filter strip/grass channel for erosion or gullying. Re-seed or sod as necessary. ► Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
► Inspect and remove any sediment and debris build-up in pretreatment areas. ► Inspect inflow points and bioretention surface for build up of road sand associated with spring melt period. Remove as necessary and replant areas that have been impacted by sand/salt build up.	Annually
► Replace mulch over the entire area. ► Replace pea gravel diaphragm or filter fabric if warranted. ► The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH.	2 to 3 years

Construction and Maintenance Costs

Once the construction plans are created, designers should utilize Table 8.22 and the cost estimation worksheet in Appendix F.

Table 8.22 lists the specific site components that are specific to bioretention devices. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.22 Cost Components for Bioretention Devices			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Preparation	Tree & plant protection	Protection Cost ($/area) x Affected Area	Removal of existing structures, topsoil removal and stockpiling
	Clearing & grubbing	Clearing Cost ($/area) x Affected Area	
	Topsoil salvage	Clearing cost ($/area) x Affected Area	
Site Formation	Excavation / grading	4-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Underdrains	Underdrain cost ($/lineal foot) x length of device	Pipes, catchbasins, manholes, valves
	Inlet structure	($/structure) or ($/curb cut)	
	Outlet structure	($/structure)	
Site Restoration	Filter strip	Sod cost ($/square foot) x filter strip area	Tree protection, soil amendments, seed bed preparation, trails
	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	
	Weed control	Labor cost ($/hour) x Hours per visit x Frequency (4x per year)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4x / 1 yr)	

Source: Adapted from EPA, 1999

E. Design Procedure

The following steps outline a recommended design procedure for bioretention practices in compliance with the Inver Grove Heights stormwater permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of an bioretention practice, and identify the function of the practice in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Site topography and slopes
- ► Soil infiltration capacity
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks

B. Determine how the bioretention practice will fit into the overall stormwater treatment system

- ► Decide whether the bioretention practice is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the bioretention practice is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with local officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the bioretention practice must comply with the MPCA Permit.

Step 3. Perform field verification of site suitability

- ► If the initial evaluation indicates that a bioretention practice would be a good BMP for the site, it is HIGHLY RECOMMENDED that a minimum of three soil borings or pits be dug (in the same location as the proposed bioretention practice) to verify soil types and infiltration capacity characteristics and to determine the depth to groundwater and bedrock.
- ► It is HIGHLY RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed bioretention practice.
- ► It is HIGHLY RECOMMENDED that soil profile descriptions be recorded and include the following information for each soil horizon or layer (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004):
    - Thickness, in inches or decimal feet
    - Munsell soil color notation
    - Soil mottle or redoximorphic feature color, abundance, size and contrast
    - USDA soil textural class with rock fragment modifiers
    - Soil structure, grade size and shape
    - Soil consistence, root abundance and size
    - Soil boundary
    - Occurrence of saturated soil, impermeable layers/lenses, groundwater, bedrock or disturbed soil
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

Step 4. Compute runoff control volumes.

Calculate the volume control standard (VCS). Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 5. Size Practice and Determine Bioretention Type (Note: Steps 5, 6, 7 and 8 are iterative)

After following the steps outlined above, the designer will presumably know the location of naturally occurring permeable soils, the depth to the water table, bedrock or other impermeable layers, and the contributing drainage area. While the first step in sizing a bioretention practice is selecting the type of design variant for the site, the basic design procedures for each type of bioretention practice are similar.

a. Volume control standard (VCS) – After determining the volume control standard for the entire site (Step 1), determine the portion of the total volume that will be treated by the bioretention facility.

b. Based on the known VCS, infiltration rates of the underlying soils and the known existing potential pollutant loading from proposed/existing landuse select the appropriate bioretention practice from Table 8.5. Note: the determination for under-drain is an iterative sizing process.

Table 8.23 Summary of Bioretention Variants for Permeability of Native Soils and Potential Landuse Pollutant Loading

Bioretention Type	Variant	Underlying Soil Performance Criteria
Infiltration/Recharge Facility	No under-drain	Higher recharge potential (facility drain time without under-drain is < 72 hours, 48 hours if used to meet MPCA reqs.)
Filtration/Partial Recharge Facility	Under-drain	Lower recharge potential (facility drain time without under-drain is < 72 hours, 48 hours if used to meet MPCA reqs.)
Infiltration/Filtration/Recharge Facility	Elevated under-drain	Higher nutrient loadings and/or quantity control
Filtration Only Facility	Under-drain with liner	Hot Spot Treatment

Information collected during the Physical Suitability Evaluation (see Step 2) should be used to explore the potential for multiple bioretention practices versus relying on a single bioretention facility. Bioretention is best employed close to the source of runoff generation and is often located in the upstream portion of the stormwater treatment train, with additional stormwater BMP's following downstream.

Infiltration Rates – If the infiltration rate is not measured, the following table provides infiltration rates for the design of infiltration practices. These infiltration rates represent the long-term infiltration capacity of a practice and are not meant to exhibit the capacity of the soils in the natural state. Select the design infiltration rate from the table based on the least permeable soil horizon within the first five feet below the bottom elevation of the proposed infiltration practice.

The infiltration capacity and existing hydrologic regime of natural basins are inheritably different than constructed practices and may not meet Inver Grove Heights permit requirements for constructed practices. In the event that a natural depression is being proposed to be used as an infiltration system, the design engineer must demonstrate the following information: infiltration capacity of the system under existing conditions (inches/hour), existing drawdown time for the high water level (HWL) and a natural overflow elevation. The design engineer should

also demonstrate that operation of the natural depression under post-development conditions mimics the hydrology of the system under pre-development conditions.

Table 8.24. Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/hour]	Soil Textures	Corresponding Unified Soil Classification
A	1.6	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands
D	< 0.2	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). The rates presented in this infiltration table use the information compiled from these sources as well as eight years of infiltration rates collected in various infiltration practices located in the South Washington Watershed District.

If the infiltration rates are measured the tests shall be conducted at the proposed bottom elevation of the infiltration practice. If the infiltration rate is measured with a double-ring infiltrometer the requirements of ASTM D3385 shall be used for the field test.

c. Area sizing for facilities with and without an under drain:

Without An Under Drain

The bioretention surface area is computed using the following equation, for those practices that are designed **without an under drain**:

$$A_f = (VCS \times d_f) / [i \times (h_f + d_f) \times t_f]$$

Where:

A_f = surface area of filter bed (ft^2)

d_f = filter bed depth (ft)
i = infiltration rate of underlying soils (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)
(2 days is the recommended maximum t_f for bioretention)

Use Table 8.19 to determine the infiltration rate of the underlying soils. Note that these numbers are intentionally conservative based on experience gained from Minnesota infiltrations sites.

With An Under Drain
The bioretention surface area is computed using the following equation, for those practices that are designed **with an under drain**:

$$A_f = (VCS \times d_f) / [k \times (h_f + d_f) \times t_f]$$

Where:

A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)
(2 days is the recommended maximum t_f for bioretention)

The following coefficients of permeability should be used for the Planting Medium / Filter Media Soil:

0.5 ft/day (Clayton and Schueler, 1996) (Note: value is conservative to account for clogging associated with accumulated sediment)

Step 6. Size outlet structure and/or flow diversion structure, if needed (Note: Steps 5, 6, 7 and 8 are iterative)

It is REQUIRED that a secondary outlet be incorporated into the design of a bioretention practice to safely convey excess stormwater.

Step 7. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps 5, 6, 7 and 8 are iterative)

Follow the design procedures identified in the Stormwater System Sizing Criteria section of the Manual (Chapter 7) to determine the volume control.

Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site (see also Chapter 9 of the manual). This includes defining the parameters of the bioretention practice defined above: sedimentation basin elevation and area (defines the pond volume), infiltration/permeability rate, and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated (back to Step 5).

Peak Discharge Rates

Outflow must be limited such that erosion does not occur down gradient of the bioretention practice.

Period of Inundation

Bioretention practices shall discharge through the soil or filter media in 72 hours or less (48 hours if its being used to meet MPCA permit requirements). Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events.

Other design requirements may apply to a particular site. The applicant should confirm local design criteria and applicability (see Step 3).

Step 8. Perform groundwater mounding analysis (Note: Steps 5, 6, 7 and 8 are iterative)

Ground water mounding, the process by which a mound forms on the water table as a result of recharge at the surface, can be a limiting factor in the design and performance of bioretention practices where infiltration is a major design component. A minimum of 3 feet of separation between the bottom of the bioretention practice and the seasonally high water table is REQUIRED (5 feet HIGHLY RECOMMENDED) to maintain the hydraulic capacity of the practice and provide adequate water quality treatment.

The most widely known and accepted analytical methods to solve for ground water mounding are based on the work by Hantush (1967) and Glover (1960). The maximum ground water mounding potential should be determined through the use of available analytical and numerical methods. Detailed ground water mounding analysis should be conducted by a trained hydrogeologist or equivalent as part of the site design procedure.

Step 9. Determine pretreatment volume and design pretreatment measures

Some form of dry or wet pretreatment is REQUIRED prior to the discharge of stormwater into the bioretention practice, to remove any sediment and fines that may result in clogging of the soils in the sediment basin area. If a grass filter strip is used, it is HIGHLY RECOMMENDED that it be sized using the guidelines in Table 8.20.

Table 8.25 Guidelines for Filter Strip Pretreatment Sizing

Parameter	Impervious Parking Lots				Residential Lawns			
Maximum Inflow Approach Length (ft.)	35		75		75		150	
Filter Strip Slope	≤2%	>2%	≤2%	>2%	≤2%	>2%	≤2%	>2%
Filter Strip Minimum Length	10’	15’	20’	25’	10’	12’	15’	18’

Grass channel sizing

It is HIGHLY RECOMMENDED that grass channel pretreatment for bioretention be a minimum of 20 feet in length and be designed according to the following guidelines:

- Parabolic or trapezoidal cross-section with bottom widths between 2 and 8 feet
- Channel side slopes no steeper than 3:1 (horizontal:vertical).
- Flow velocities limited to 1 foot per second or less for peak flow associated with the water quality event storm (i.e., 0.5 or 1.0 inches depending on watershed designation).
- Flow depth of 4 inches or less for peak flow associated with the water quality event storm.

Step 10. Prepare Vegetation and Landscaping Plan
See Major Design Elements for guidance on preparing vegetation and landscaping management plan.

Step 11. Prepare Operations and Maintenance (O&M) Plan
See Operations and Maintenance for guidance on preparing an O&M plan.

F. Links to other Manuals

Price George's County Programs & Planning Division Department of Environmental Resources. 2002. *Bioretention Manual*. Landover, MD.

G. References

Davis, A.P., M. Shokouhian, H. Sharma and C. Minani. 1998. Optimization of *Bioretention for Design for Water Quality and Hydrologic Characteristics.* n.p.

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual, Stormwater Best Management Practice for Cold Climates*. St. Paul, MN.

Price George's County Programs & Planning Division Department of Environmental Resources. 2002. *Bioretention Manual*. Landover, MD.

Low Impact Design Center, Inc. 2005. *Urban Design Tools*, Internet Resource. Beltsville, MD. http://www.lid-stormwater.net

State of New Jersey, Department of Watershed Management. 2004. *New Jersey Stormwater Best Management Practices Manual*. NJ.

International Stormwater Best Management Practices (BMP) Database. http://www.bmpdatabase.org/.

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.

Prince Georges' County Maryland. 2002. Bioretention Manual.

Vermont Stormwater Management Manual. 2002. http://www.vtwaterquality.org/stormwater.htm.

Winer, R. 2000. National Pollutant Removal Performance Database.

Wisconsin DNR Bioretention for Infiltration Conservation Practice Standard 1004. 2004. http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

INFILTRATION PRACTICES



Lino Lakes City Hall - Infiltration trench
Lino Lakes, MN



Bradshaw Celebration of Life Center - underground storage & infiltration
Stillwater, MN

Definition:
Natural or constructed depressions located in permeable soils that capture, store and infiltrate the volume of stormwater runoff associated with a particular design event.

KEY CONSIDERATIONS

Design Criteria:
- Contributing drainage area
- Underlying soil types
- Depth to the water table, bedrock or other impeding layer
- Proximity to buildings, drinking water supplies, Karst features, etc.
- Source of stormwater runoff

Benefits:
- Reduces volume of stormwater runoff
- Increases ground water recharge
- Improves surface water quality
- Provides thermal benefits (e.g. to cold water fisheries)
- Mimics pre-development hydrology

Limitations:
- Unusual construction considerations
- Potential for ground water contamination
- Tendency to lose effectiveness over time due to clogging – if not properly constructed or maintained
- Not recommended for areas with steep slopes
- May require landscaping: consideration should be given to periods oF inundation and drought

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X*	Transpiration *if vegetated
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

95%	Total Suspended Solids
65%/ 50%	Nutrients - Total Phosphorus/ Total Nitrogen
95%	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Coliform, Streptococci, E. Coli
NA	Toxins - Chloride, Hydrocarbon, Pesticide

INFILTRATION PRACTICES

SITE FACTORS

1/ 5/ 50 AC Max	Drainage Areas: Dry Well/ Trench/ Basin
20%	Max. Site Slope
3’	Min. Depth to Bedrock
3’	Min. Depth to Seasonally High Water Table
A,B,C*,& D*	NRCS Soil Type *C & D soils have limited infiltration ability but can be used to match pre-development conditions
Poor - Good	Freeze/ Thaw Suitability

Description:
In general terms, infiltration systems can be described as natural or constructed depressions located in permeable soils that capture, store and infiltrate stormwater runoff within 72 hours (48 hours if they’re being used to meet MPCA permit requirements). These depressions can be located at the surface of the ground (e.g. infiltration basin) or they can be designed as underground facilities (e.g. structural chamber or excavated pit filled with aggregate such as an infiltration trench). Typically, infiltration systems are designed with one or more pre-treatment facilities or they are designed as off-line facilities.

Infiltration systems should be located in permeable soils and a minimum 3-foot distance is REQUIRED from the bottom of the practice to the seasonally high water table, bedrock or other impeding layer per the Minnesota Pollution Control Agency Construction General Permit (CGP). Dry wells and Trenches should be designed to handle the smaller, more frequent rainfall events. Stormwater associated with the larger rainfall events should bypass these practices by a separate pipe or an overflow device. Infiltration basins and underground infiltration systems should be designed to handle both the water quality volume and as the water quantity volume.

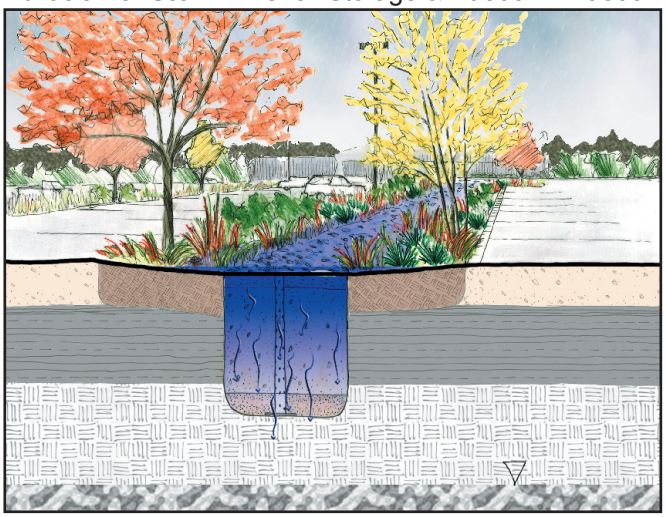
Infiltration systems can be designed to address a number of stormwater management issues including: water quality, stormwater runoff reduction, flow attenuation, thermal impacts to cold water fisheries, and ground water recharge.

STORM SEQUENCE

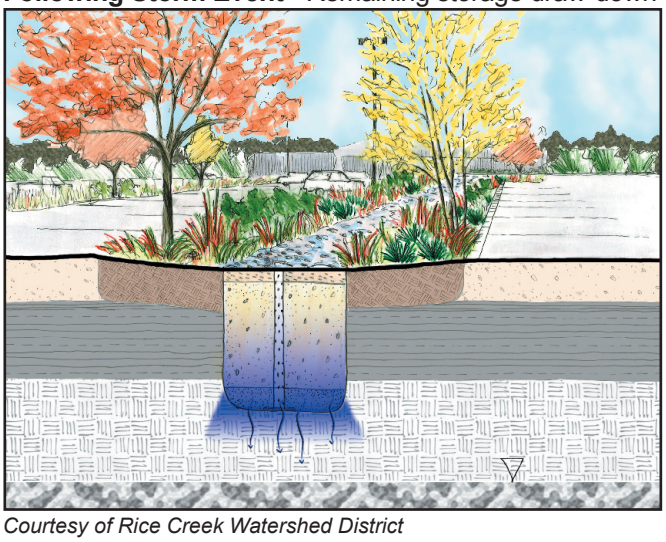
Start of Storm Event - Initial runoff & storage



Duration of Storm Event - Storage & filtration/infiltration



Following Storm Event - Remaining storage draw-down



Courtesy of Rice Creek Watershed District

A. Suitability

General

Stormwater infiltration practices capture and temporarily store stormwater before allowing it to infiltrate into the soil. Design variants include; the infiltration basin, the infiltration trench, the dry well and the underground infiltration system. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants and delay peak stormwater flows. Infiltration practices are applicable to sites with naturally permeable soils and a suitable distance to the seasonally high groundwater table, bedrock or other impermeable layer. They may be used in residential and other urban settings where elevated runoff volumes, pollutant loads, and runoff temperatures are a concern. In applications where the stormwater runoff has a particularly high pollutant load or where the soils have very high infiltration rates, a significant amount of pretreatment should be provided to protect the groundwater quality.

Function Within Stormwater Treatment Train

Infiltration practices may be located at the end of the treatment train or they can be designed as off-line configurations where the volume control standard volume is diverted to the infiltration practice. In any case, the practice may be applied as part of a stormwater management system to achieve one of the following objectives:

- ► reduce stormwater pollutants
- ► increase groundwater recharge
- ► decrease runoff peak flow rates
- ► decrease the volume of stormwater runoff
- ► preserve base flow in streams
- ► reduce thermal impacts of runoff

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard (VCS). This standard must be met on all new and re-development projects taking place in the northwest area.

Infiltration systems may reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate. Infiltration areas are expected to make up a large portion of the 5-year 24-hour volume control standard.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

- ***Infiltration Basin*** – An infiltration basin is a natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. Infiltration basins are commonly used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent. Typical depths range from 2 to 12 feet, including bounce in the basin.
- ***Infiltration Trench (a.k.a. infiltration gallery)*** – An infiltration trench is a shallow excavated trench, typically 3 to 12 feet deep, that is backfilled with a coarse stone aggregate allowing for the temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Trenches are commonly used for drainage areas less than 5 acres in size.
- ***Dry Wells (a.k.a. infiltration tubes, french drains, soak-away pits or soak holes)*** – A dry well or soak away pit is a smaller variation of an infiltration trench. It is a subsurface storage facility (a structural chamber or an excavated pit backfilled with a coarse stone aggregate) that receives and temporarily stores stormwater runoff. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size (e.g. roof tops).
- ***Underground Infiltration Systems*** – Several underground infiltration systems, including pre-manufactured pipes, vaults, and modular structures, have been developed as alternatives to infiltration basins and trenches for space-limited sites and stormwater retrofit applications. These systems are similar to infiltration basins and trenches in that they are designed to capture, temporarily store and infiltrate the design volume of stormwater over several days. Underground infiltration systems are generally applicable to small development sites (typically less than 10 acres) and should be installed in areas that are easily accessible to routine and non-routine maintenance. These systems should not be located in areas or below structures that cannot be excavated in the event that the system needs to be replaced.

Note: There is some concern that underground infiltration systems and dry wells meet the U.S. Environmental Protection Agency (EPA) definition of a Class V injection well. Class V injection wells are defined as any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (U.S. Environmental Protection Agency, When are Storm Water Discharges Regulated as Class V Well, June 2003).

Retrofit Suitability

The narrow and versatile shape of infiltration trenches and dry wells makes them well suited for retrofit projects. For example, infiltration practices can be situated along the margin or perimeter of a developed site or roadway in many cases. They are particularly desirable as retrofit practices in watersheds or catchments that are targeting volume reduction practices to help minimize channel erosion. Caution should be used when implementing infiltration practices for treatment of runoff from industrial areas with exposed significant materials or from vehicle fueling and maintenance areas. Generally, infiltration should not be used to treat runoff from manufacturing or industrial sites or other areas with high pollutant concentrations unless correspondingly high levels of pretreatment are provided. Pre-approval from City staff should be obtained in the early planning stages.

Cold Climate Suitability

Various options for use of infiltration are available for treating snowmelt runoff. Some of the installations are built below the frost line (trenches, sub-grade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is HIGHLY RECOMMENDED for surface systems.

The problem with infiltration in cold weather is the ice that forms both over the top of the facility and within the soil interstices. To avoid these problems to the extent possible, it is HIGHLY RECOMMENDED that the facility be actively managed to keep it dry before it freezes in the late fall. This can be done by various methods, including limiting inflow, under-drainage, and surface disking.

Even if the infiltration properties of an infiltration practice are marginal for snowmelt runoff, the storage available in the facility will provide some storage if it is dry entering the melt season. Routing the first high-soluble portions of snowmelt to an infiltration facility provides the opportunity for soil treatment (filtration, adsorption, microbial activity) of these solubles. Again, however, flow originating in an industrial area, a high traffic area where large amounts of salt are added, or another PSH should be diverted away from infiltration systems.

Proprietary, sub-grade infiltration systems provide an alternative to standard surface based systems. Essentially, these systems provide an insulated location for **pre-treated** snowmelt to be stored and slowly infiltrated, or simply filtered and drained away if groundwater sensitivity is an issue. The insulating value of these systems adds to their appeal as low-land-consumption alternatives to ponds and surface infiltration basins.

Water Quantity Treatment

The amount of stormwater volume infiltrated depends on the design variant selected. Smaller infiltration practices (e.g. infiltration trenches) should either be designed off-line using a flow diversion, or designed to safely pass large storm flows while still protecting the infiltration area. In many cases in Inver Grove Heights (e.g. extremely permeable soils), these smaller infiltration practices can accommodate the volume control standard (VCS)

Due to their size, the larger infiltration practices (e.g. infiltration basins and underground infiltration systems) have the potential to provide greater water quantity benefits due to their size. Surcharge storage above the practice bottom is available for detention. Outlet structures can be sized to partially or fully accommodate larger storm peak discharge control while allowing the volume below the outlet to infiltrate.

Water Quality Treatment

Infiltration practices can remove a wide variety of stormwater pollutants through chemical and bacterial degradation, sorption, and filtering. Surface water load reductions are also realized by virtue of the reduction in runoff volume. Due to the logistical challenges presented in structuring a study design, the number of scientific studies documenting the pollutant removal capability of infiltration practices is limited. However, pollutant removal and effluent concentration data for select parameters are provided in Tables 8.26 and 8.27, respectively.

Table 8.26. Percent Removal of Key Pollutants by Infiltration Practices (Winer, 2000)

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Infiltration Practices[3]	95	80	50	95[2]	ND	ND

Notes
1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement, which is not on the list of approved practices.

ND: No Data

Source: Winer, 2000

Table 8.27. Typical BMP Effluent Concentrations (Winer, 2000)

Practice Group	TSS	TP	TN	Cu[1]	Zn[1]
Infiltration Practices[2]	17	0.05	3.8	4.8	39

1. Units for Zn and Cu are micrograms per liter
2. Data based on fewer than five data points

Source: Winer, 2000

Limitations

The following general limitations should be recognized when considering installation of infiltration practices:

- Limited monitoring data are available and field longevity is not well documented
- Failure can occur due to improper siting, design, construction and maintenance
- Systems are susceptible to clogging by sediment and organic debris
- There is a risk of groundwater contamination depending on subsurface conditions, land use and aquifer susceptibility
- They are not ideal for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads
- Not recommended for areas with steep slopes.

B. Major Design Elements

Physical Feasibility Initial Check

- ***Drainage Area*** – It is HIGHLY RECOMMENDED that the following infiltration practices be designed with the indicated maximum drainage areas:
  - Dry well – 1 acre
  - Infiltration Trench – 5 acres
  - Underground Infiltration System – 10 acres
  - Infiltration Basin – between 5 and 50 acres.

- ***Site Topography and Slopes*** – Unless slope stability calculations demonstrate otherwise, it is HIGHLY RECOMMENDED that infiltration practices be located a minimum horizontal distance of 200 feet from

down gradient slopes greater than 20%, and that slopes in contributing drainage areas be limited to 15%.

- ***Soils*** – It is HIGHLY RECOMMENDED that native soils in proposed infiltration areas have a minimum infiltration rate of 0.2 inches per hour (typically Hydrologic Soil Group A, B and C soils). Initially, soil infiltration rates can be estimated from NRCS soil data, and confirmed with an on-site infiltration evaluation or geotechnical investigation (see step 3 under Design Procedures). It is HIGHLY RECOMMENDED that native soils have silt/clay contents less than 40% and clay content less than 20%, and that infiltration practices not be situated in fill soils.
- ***Depth to Ground Water Table and Bedrock*** – It is REQUIRED that infiltration practices be designed with a minimum vertical distance of 3 feet between the bottom of the infiltration practice and the seasonally high water table or bedrock layer (see also Step 8 under the Design Procedure section). Local authorities may require greater separation depths.
- ***Site Location / Minimum Setbacks*** – It is HIGHLY RECOMMENDED that infiltration practices not be hydraulically connected to structure foundations or pavement, to avoid seepage and frost heave concerns, respectively. If groundwater contamination is a concern, it is RECOMMENDED that groundwater mapping be conducted to determine possible connections to adjacent groundwater wells. The following minimum setbacks are REQUIRED by the Minnesota Department of Health for the design and location of infiltration practices. It will be necessary to consult local ordinances for further guidance on siting infiltration practices.

Table 8.28. Minimum setback requirements (Minnesota Department of Health).

Setback from	Minimum Distance [feet]
Property Line	10
Building Foundation*	10
Private Well	50
Public Water Supply Well	50
Septic System Tank/Leach Field	35
* Minimum with slopes directed away from the building.	

Source: Minnesota Department of Health

Conveyance

It is HIGHLY RECOMMENDED that a flow splitter or diversion structure be provided to divert the VCS to the infiltration practice and allow larger flows to bypass the practice, unless the infiltration practice is sized to retain larger storms. Where a flow splitter is not used, it is HIGHLY RECOMMENDED that contributing drainage areas be limited to the appropriate size given the BMP and an overflow be provided within the practice. It is also HIGHLY RECOMMENDED that the designer evaluate the potential for erosion to downstream of infiltration facilities.

Pretreatment

- It is REQUIRED that some form of pretreatment, such as a sand filter, filter strip, sedimentation basin, grass channel, or a combination of these practices be installed upstream of the infiltration practice. Pretreatment standards for infiltration practices in Inver Grove Heights state that the VCS must be treated to 85%. The developer has the responsibility to show how this will be accomplished and it must be approved by the city engineer. More information on pretreatment is available in Chapter 7.

Treatment

- ***Space Occupied*** – Varies depending on the depth of the practice. Typically, infiltration trenches are three to twelve feet deep with a width less than 25 feet. A dry well is essentially a smaller version of an infiltration trench, consistent with the fact that the drainage area to an infiltration trench is typically five times greater (or larger) than that of a dry well. Underground infiltration systems are larger practices that range in depth from approximately 2 to 12 feet. The surface area of all infiltration practices is a function of the 72-hour drawdown requirement (48-hour drawdown if its being used to meet MPCA permit requirements) and the infiltration capacity of the underlying soils.
- ***Practice Slope*** – It is RECOMMENDED that the bottom of all infiltration practices be flat, in order to enable even distribution and infiltration of stormwater. It is RECOMMENDED that the longitudinal slope range only from the ideal 0% up to 1%, and that lateral slopes be held at 0%.
- ***Side Slopes*** – It is HIGHLY RECOMMENDED that the maximum side slopes for an infiltration practice be 3:1 (h:v).
- ***Depth*** – The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate. The REQUIRED drawdown time for infiltration practices is 72 hours or less (48 hours or less if used to meet MPCA permit requirements) and so the depth of the practice should be determined accordingly.
- ***Groundwater Protection*** – It is REQUIRED that runoff from potential stormwater hotspots (PSHs) not be infiltrated unless adequate pretreatment has been provided and pre-approval from City staff is obtained.
- ***Aesthetics*** – Infiltration basins can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. Infiltration trenches are less conducive to site aesthetics, but the surface of trenches can be designed with turf cover crops if desired.

Landscaping

- It is REQUIRED that impervious area construction be completed and pervious areas established with dense and healthy vegetation prior to introduction of stormwater into an infiltration practice.
- It is RECOMMENDED that vegetation associated with infiltration practices be established to blend into the surrounding area, that native species be used wherever possible. It is HIGHLY RECOMMENDED that deep rooted plants such as prairie grass be used, because they increase the infiltration capacity of the underlying soils. Dry wells and infiltration trenches can be covered with permeable topsoil and planted with grass to match the surrounding landscape.
- Due to soil compaction concerns, it is HIGHLY RECOMMENDED that infiltration areas not be used for recreational purposes.
- It is HIGHLY RECOMMENDED that vegetation associated with infiltration practices be regularly maintained and bare areas seeded. Mowing practices can be used to maintain native vegetation.
- It is RECOMMENDED that soil testing be conducted in infiltration practices, to determine if fertilizer application is warranted. Incorporating mulch or compost into the soil or planting with salt tolerant grasses can counter soil fertility problems caused by high chloride concentrations.

Safety

- Dry wells, infiltration trenches and subsurface infiltration systems do not pose any major safety hazards. Infiltration basins should have similar side slope considerations as ponds and wetlands.
- If a dry well or infiltration trench is greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930
- When riser pipe outlets are used in infiltration basins, it is HIGHLY RECOMMENDED that be constructed with manholes that either have locks or are sufficiently heavy to prevent easy removal.
- Fencing of dry wells and infiltration trenches is neither necessary nor desirable. Infiltration basins may warrant fencing in some situations.

Construction Details

CADD based details for infiltration systems are contained in Appendix A. The following details, with specifications, have been created for infiltration systems:

- Infiltration Basin
- Infiltration Trench
- Subsurface Infiltration System
- Inlet/Outlet Structures

C. Construction Specifications

Given that the construction of infiltration practices incorporates techniques or steps which may be considered non-standard, it is RECOMMENDED that the construction specifications include the following format and information.

I. Temporary Erosion Control
- Installation prior to site disturbance
- Catch basin/inlet protection
- Use of BMP as temporary sedimentation basin

II. Excavation, Backfill and Grading
- Timing of grading of infiltration practices (relative to total site development)
- Use of low-impact, earth moving equipment
- Do not over-excavate
- Restoration in the event of sediment accumulation during construction of practice
- Gravel backfill specifications
- Gravel filter specifications
- Filter fabric specifications
- Observation well specifications

III. Native Plants, Planting and Transplanting (MN Plant List in Appendix B of the Manual)
- Site preparation of planting areas
- Timing of native seeding and native planting
- Weed control
- Watering of plant material

IV. Construction Sequence Scheduling
- Temporary construction access
- Location of silt fence installation to protect BMPs and downgradient receiving waters
- Removal and storage of excavated material
- Installation of underground utilities
- Rough grading
- Seeding and mulching disturbed areas
- Road construction
- Final grading
- Site stabilization
- Installation of semi-permanent and permanent erosion control measures
- Silt fence removal

V. Construction Observation
- Adherence to construction documents
- Verification of physical site conditions
- Erosion control measures installed appropriately

D. Operation and Maintenance

Overview

Effective long-term performance of infiltration practices requires an infiltration management plan (REQUIRED), performance monitoring (HIGHLY RECOMMENDED), and a dedicated and routine maintenance schedule with clear guidelines and schedules (REQUIRED).

The infiltration management plan (operation plan) should address the following items: periods of inundation, wet/dry cycling of soils, operating instructions for drawdown valves, gates and removable weirs.

The monitoring plan should address the following items: Inspection and Efficiency Assessment, water quality monitoring, monitoring of groundwater elevations, long-term infiltration capacity and plant tolerances.

Elements to be considered for the development of a maintenance plan are broken into the following categories: Design Phase Maintenance Considerations; Construction Phase Maintenance Considerations; and Post-Construction Maintenance Considerations. In general terms, the most frequently cited maintenance concern for infiltration practices is clogging caused by organic matter and fine silts. Common operational problems include:

- Clogging and sediment deposition
- Erosion of contributing land or in channels leading to the practice
- Maintaining appropriate surface vegetation

Table 8.29 provides a summary of common problems for infiltration trenches and basins.

Table 8.29 Typical Maintenance Problems for Infiltration Trenches and Basins

Problem	Practices Applied To	Comments
Clogging, sediment deposition	Both	Key issue for infiltration practice. Requires vigilant inspection and maintenance.
Surface Vegetation	Both	Often important to maintain vigorous growth at the base of infiltration practices (basins). Important to restrict woody vegetation from the surface of infiltration trenches.
Erosion of contributing land or in channels leading to practice	Both	In these practices, it is important to monitor not only the practice itself, but also upland infiltration to minimize the sediment load.
Damage to filter fabric	Trench	Infrequent but important maintenance concern.
Scouring at Inlet	Both	Similar issues to Ponds. Need to promote non-erosive flows that are evenly distributed
Access Issues	Both	Similar issues to Ponds. Need access for inspection and maintenance.
Concrete Failure	Basins, if they include a riser structure	Similar issues to ponds and wetlands.
Problems with the Embankment	Basins	Similar issues to dry ponds.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections is the fact that many design elements for infiltration systems can minimize the maintenance burden and maintain pollutant removal efficiency. Among them are:

- Providing easy access (typically 8 feet wide) to infiltration practices for routine maintenance is REQUIRED. Open lawn areas are RECOMMENDED locations for infiltration practices because of their accessibility.
- It is REQUIRED that a way to visually verify proper system operation be installed with each infiltration practice. It is REQUIRED that every dry well, infiltration trench and subsurface infiltration system design include an observation well consisting of an anchored six-inch diameter perforated PVC pipe fitted with a cap to facilitate periodic inspection and maintenance. It is also REQUIRED that infiltration basins include a draw down device that can be used for winter diversion and to conduct regular maintenance.
- It is HIGHLY RECOMMENDED that a mechanism such as a multi-stage outlet structure be incorporated into the design of the pretreatment and infiltration practices to facilitate draining for maintenance purposes.

Construction Phase Maintenance Considerations

Infiltration practices are particularly vulnerable during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the practice. In addition, heavy construction can result in compaction of the soil, which can then reduce the soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Critical construction elements for infiltration practices are as follows:

- ***Avoid excessive compaction***
  It is REQUIRED that in order to prevent soil compaction, the proposed infiltration area be staked off and marked during construction to prevent heavy equipment and traffic from traveling over it. In addition, it is HIGHLY RECOMMENDED that the side walls of dry wells and infiltration trenches be roughened if they have been smeared by heavy equipment.
- ***Stabilize Vegetation Before and After Construction***
  Excessive sediment loadings can occur without the use of proper erosion and sediment control practices during the construction process. It is REQUIRED that upland drainage areas be properly stabilized with a thick layer of vegetation, particularly immediately following construction, to reduce sediment loads. If infiltration practices are in-place during construction activities, it is REQUIRED that sediment and runoff be kept away the infiltration area, such as with diversion berms and soil-stabilizing vegetation around the perimeter of the practice.
- ***Correctly Install Filter Fabrics***
  Large tree roots should be trimmed flush with the sides of dry wells and infiltration trenches to prevent puncturing or tearing of the filter fabric during subsequent installation procedures. When laying out the geotextile, the width should include sufficient material to compensate for perimeter irregularities in the dry well or trench and for a 6-inch minimum top overlap. The filter fabric itself should be tucked under the sand layer on the bottom of the dry well of infiltration trench, and stones or other anchoring objects should be placed on the fabric at the trench sides to keep the excavation open during windy periods. Voids may occur between the fabric and the excavated sides of the practice. Natural soils should be placed in any voids to ensure fabric conformity to the excavation sides.
- ***Carefully Finish Final Grading***
  Initial infiltration basin excavation should be carried to within 2 feet of the final elevation of the basin floor. It is REQUIRED that infiltration systems not be excavated to final grade until the contributing drainage area has been constructed and fully stabilized. The final phase excavation should remove all

accumulated sediment and be done by light tracked equipment to avoid compaction of the basin floor and provide a well-aerated, highly porous surface texture.

- ***Keep Infiltration Practices "Off-line" until Construction Is Complete***
  It is REQUIRED that sediment and runoff be kept completely away from the infiltration area during construction. Thus, infiltration practices should never serve as sediment control devices during site construction. It is HIGHLY RECOMMENDED that construction of infiltration practices be suspended during snowmelt or rainfall, in order to prevent soil smearing, clumping, or compaction.
- ***Establish Permanent Vegetation***
  Establishing dense vegetation on the basin side slopes is HIGHLY RECOMMENDED, to reduce erosion and sloughing and provide a natural means of maintaining relatively high infiltration rates. Vegetative cover at inflow points to the basin is also HIGHLY RECOMMENDED to provide erosion protection and reduce sediment accumulation. The use of native grasses is RECOMMENDED for seeding primarily due to their adaptability to local climates and soil conditions.

Inspections during construction are needed to ensure that the infiltration practice is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction to ensure that the contractor's interpretation of the plan is acceptable to the designer. An example construction phase inspection checklist for both infiltration basins and infiltration trenches are provided in Appendix D.

Post-construction Operation and Maintenance

A maintenance plan clarifying maintenance responsibility is REQUIRED. Effective long-term operation of infiltration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Some important post-construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D.

- A legally binding and enforceable maintenance agreement should be executed between the practice owner and the local review authority.
- Adequate access must be provided for all infiltration practices for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles.
- General infiltration trench maintenance activities and schedule are provided in Table 8.30.

Table 8.30 Typical Maintenance Activities for Infiltration Trenches

Activity	Schedule
► Replace pea gravel/topsoil and top surface filter fabric (when clogged).	As needed
► Ensure that contributing area, practice and inlets are clear of debris. ► Ensure that the contributing area is stabilized. ► Remove sediment and oil/grease from pretreatment devices, as well as overflow structures. ► Mow grass filter strips should be mowed as necessary. Remove grass clippings. ► Repair undercut and eroded areas at inflow and outflow structures	Monthly
► Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. ► Inspect pretreatment devices and diversion structures for sediment build-up and structural damage. ► Remove trees that start to grow in the vicinity of the trench.	Semi-annual Inspection

Table 8.30 Typical Maintenance Activities for Infiltration Trenches	
Activity	**Schedule**
► Disc or otherwise aerate basin bottom. De-thatch basin bottom.	Annually
► Scrape basin bottom and remove sediment. Restore original cross-section and infiltration rate. Seed or sod to restore ground cover.	Every 5 years
► Perform total rehabilitation of the trench to maintain design storage capacity. ► Excavate trench walls to expose clean soil.	Upon Failure

Source:EPA, 1999

Construction and Maintenance Costs

Table 8.31 lists the specific site components that are specific to infiltration practices. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.31 Infiltration Practices Cost Components			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Infiltration area protection	Silt fence cost ($/'foot) x Perimeter of infiltration area	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
	Topsoil salvage	Salvage Cost ($/acre) x Affected Area	
Site Formation	Excavation / grading	X-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	

Table 8.31 Infiltration Practices Cost Components			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Structural Components	Vault structure (for underground infiltration)	($/structure)	Pipes, catchbasins, manholes, valves, vaults
	Media (for infiltration trenches)	Media cost ($/cubic yard) x filter volume (cubic yard)	
	Geotextile	Geotextile cost ($/cy) x area of trench, including walls	
	Inlet structure	($/structure)	
	Overflow structure	($/structure)	
	Observation well	($/structure)	
	Filter strip	Sod cost ($/square foot) x filter strip area	
Site Restoration	Soil preparation	Topsoil or amendment cost ($/acre) x Area (acre)	Tree protection, soil amendments, seed bed preparation, trails
	Seeding	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1x / 5yr)	Vegetation maintenance, cleaning of structures
	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2x / 1yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (6x / 1 yr)	
	Mowing (for some vegetative filters)	Mowing Cost ($) x Mowing Frequency (6x / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for infiltration practices in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of an infiltration practice, and identify the function of the practice in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area

- ► Site topography and slopes greater than 20%
- ► Soil infiltration capacity
- ► Regional or local depth to groundwater and bedrock
- ► Site Location/Minimum setbacks
- ► Presence of active Karst

B. Determine how the infiltration practice will fit into the overall stormwater treatment system

- ► Decide whether the infiltration practice is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
- ► Decide where on the site the infiltration practice is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Check with local officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
B. Determine whether the infiltration practice must comply with the MPCA Permit.

Step 3. Perform field verification of site suitability

- ► If the initial evaluation indicates that an infiltration practice would be a good BMP for the site, it is HIGHLY RECOMMENDED that a minimum of three **soil borings or pits** be dug (in the same location as the proposed infiltration practice) to verify soil types and infiltration capacity characteristics and to determine the depth to groundwater and bedrock.
- ► It is HIGHLY RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed infiltration practice.
- ► It is HIGHLY RECOMMENDED that soil profile descriptions be recorded and include the following information for each soil horizon or layer (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004):
  - Thickness, in inches or decimal feet
  - Munsell soil color notation
  - Soil mottle or redoximorphic feature color, abundance, size and contrast
  - USDA soil textural class with rock fragment modifiers
  - Soil structure, grade size and shape
  - Soil consistence, root abundance and size
  - Soil boundary
  - Occurrence of saturated soil, impermeable layers/lenses, groundwater, bedrock or disturbed soil
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

Step 4. Compute runoff control volumes.

Calculate the volume control standard (VCS). Details on the Unified Stormwater Sizing Criteria are found in Chapter 7.

If the infiltration practice is being designed to meet the requirements of the Inver Grove Heights Permit, the REQUIRED infiltration volume is the VCS. If part of the overall VCS is to be infiltrated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be infiltrated by the infiltration practice.

Step 5. Select design variant based on Physical Suitability Evaluation

Once the Physical Suitability Evaluation is complete, it is HIGHLY RECOMMENDED that the designer apply the Better Site Design principles in sizing and locating the infiltration practice(s) on the development

site. Given the volume control standard and the drainage area, select the appropriate infiltration practice for the first iteration of the design process.

Table 8.32 Summary of Infiltration Practices for Given Drainage Areas.	
Infiltration Practice	**Drainage Area**
Infiltration Basin	5 to 50 acres
Infiltration Trench	less than 5 acres
Dry Wells	less than one acre
Underground Infiltration Systems	less than 10 acres

Note: Information collected during the site suitability evaluation (see Steps 1 and 3) should be used to explore the potential for multiple infiltration practices versus relying on a single infiltration facility. The use of smaller infiltration practices dispersed around a development is usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems (Source: Site Evaluation for Stormwater Infiltration, Wisconsin Department of Natural Resources Conservation Practice Standards 2004).

Step 6. Size infiltration practice (Note: Steps 5, 6, 7 and 8 are iterative)

After following the steps outlined above, the designer will presumably know the location of naturally occurring permeable soils, the depth to the water table, bedrock or other impermeable layer, and the contributing drainage area. While the first step in sizing an infiltration practice is selecting the type of infiltration practice for the site, the basic design procedures are very similar.

- ***Infiltration Location*** – Given the steps performed in the Physical Suitability Evaluation, identify the most suitable location for the infiltration practice. Pretreatment prior to infiltration is REQUIRED to remove total suspended solids and other pollutants associated with stormwater (see Step 9).
- ***Infiltration Rates*** – **If the infiltration rate is not measured**, the following table provides infiltration rates for the design of infiltration practices. These infiltration rates represent the long-term infiltration capacity of a practice and are not meant to exhibit the capacity of the soils in the natural state. Select the design infiltration rate from the table based on the least permeable soil horizon within the first five feet below the bottom elevation of the proposed infiltration practice.

Table 8.33 Design Infiltration Rates			
Hydrologic Soil Group	**Infiltration Rate [inches/ hour]**	**Soil Textures**	**Corresponding Unified Soil Classification**
A	1.6	Gravel, sandy gravel and silty gravels	**GW** - Well-graded gravels, sandy gravels **GP** – Gap-graded or uniform gravels, sandy gravels **GM** - Silty gravels, silty sandy gravels **SW** - Well-graded, gravelly sands
	0.8	Sand, loamy sand or sandy loam	**SP** - Gap-graded or uniform sands, gravelly sands

Table 8.33 Design Infiltration Rates

Hydrologic Soil Group	Infiltration Rate [inches/ hour]	Soil Textures	Corresponding Unified Soil Classification
B	0.6	Silt loam	**SM** - Silty sands, silty gravelly sands
	0.3	Loam	**MH** – Micaceous silts, diatomaceous silts, volcanic ash
C	0.2	Sandy clay loam	**ML** - Silts, very fine sands, silty or clayey fine sands
D	< 0.2	Clay loam, silty clay loam, sandy clay, silty clay or clay	**GC** – Clayey gravels, clayey sandy gravels **SC** – Clayey sands, clayey gravelly sands **CL** – Low plasticity clays, sandy or silty clays **OL** – Organic silts and clays of low plasticity **CH** – Highly plastic clays and sandy clays **OH** – Organic silts and clays of high plasticity

Source: Thirty guidance manuals and many other stormwater references were reviewed to compile recommended infiltration rates. All of these sources use the following studies as the basis for their recommended infiltration rates: (1) Rawls, Brakensiek and Saxton (1982); (2) Rawls, Gimenez and Grossman (1998); (3) Bouwer and Rice (1984); and (4) Urban Hydrology for Small Watersheds (NRCS). SWWD, 2005, provides field documented data that supports the proposed infiltration rates.

The infiltration capacity and existing hydrologic regime of natural basins are inheritably different than constructed practices and may not meet the Permit requirements for constructed practices. In the event that a natural depression is being proposed to be used as an infiltration system, the design engineer must demonstrate the following information: infiltration capacity of the system under existing conditions (inches/hour), existing drawdown time for the high water level (HWL) and a natural overflow elevation. The design engineer should also demonstrate that operation of the natural depression under post-development conditions mimics the hydrology of the system under pre-development conditions.

If the infiltration rates are measured[1] the tests shall be conducted at the proposed bottom elevation of the infiltration practice. If the infiltration rate is measured with a double-ring infiltrometer the requirements of ASTM D3385 shall be used for the field test.

The measured infiltration rate shall be divided by a correction factor selected from Table 8.34. The correction factor adjusts the measured infiltration rates for the occurrence of less permeable soil horizons below the surface and the potential variability in the subsurface soil horizons throughout the infiltration site. This correction factor also accounts for the long-term infiltration capacity of the stormwater management facility.

To select the correction factor from Table 8.34, determine the ratio of the design infiltration rates for each location an infiltration measurement was performed. To determine this ratio, the design infiltration rate (Table 8.28) for the surface textural classification is divided by the design infiltration rate for the least permeable soil horizon. For example, a device with a loamy

sand at the surface and least permeable layer of loam will have a design infiltration rate ratio of about 2.7 and a correction factor of 3.5. The depth of the least permeable soil horizon should be within five feet of the proposed bottom of the device or to the depth of a limiting layer.

Table 8.34 Total Correction Factors Divided into Measured Infiltration Rates

Ratio of Design Infiltration Rates[2]	Correction Factor
1	2.5
1.1 to 4.0	3.5
4.1 to 8.0	4.5
8.1 to 16.0	6.5
16.1 or greater	8.5

[1] The method used to evaluate measured infiltration rates was developed by the Wisconsin Department of Natural Resources and is published in *Site Evaluation for Stormwater Infiltration (1002) Wisconsin Department of Natural Resources Conservation Practice Standards 02/04*.

[2] Ratio is determined by dividing the design infiltration rate (Table 8.33) for the textural classification at the bottom of the infiltration device by the design infiltration rate (Table 8.33) for the textural classification of the least permeable soil horizon. The least permeable soil horizon used for the ratio should be within five feet of the bottom of the device or to the depth of the limiting layer.

- ***Depth*** – The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate. Given the assumed infiltration rate for the practice, determine the maximum depth as follows:

$$D = i \times t$$

Where:

D	=	maximum depth of practice (inches)
i	=	infiltration rate (inches/hour)
t	=	maximum drawdown time (72 hours, 48 hours for MPCA permit)

- ***Effective Infiltration Area*** – Given the volume control standard (VCS) and the maximum depth of the practice (D) calculate the effective infiltration area where the effective infiltration area is defined as the area of the facility that is used to infiltrate runoff and does not include the area used for site access, berms and/or pretreatment.

For above ground practices that are rectangular in nature (infiltration basins with 3:1 side slopes or steeper)

$$A_i = V_w/D$$

Where:

A_i	=	effective infiltration area at the bottom of practice (ft^2)
V_w	=	design volume (e.g. VCS) (ft^3)
D	=	maximum depth of practice (feet) Note: *bottom of the infiltration practice should be at least three feet from the seasonally high groundwater table.*

For above ground practices that have angular sides slopes (infiltration basins with sides slopes shallower that 3:1)

$A_i = V_w/D$

Where:

A_i	=	effective infiltration area at half the volume of the practice* (*see Figure 8.11 below)* (ft^2)
V_w	=	design volume (e.g. VCS) (ft^3)
D	=	maximum depth of practice (feet) Note: *bottom of the infiltration practice should be at least three feet from the seasonally high groundwater table.*

* Since there is potentially a significant amount of infiltration that could occur though the sides of the practice, the design engineer should take this surface area into consideration thereby potentially reducing the overall footprint of the stormwater infiltration practice.

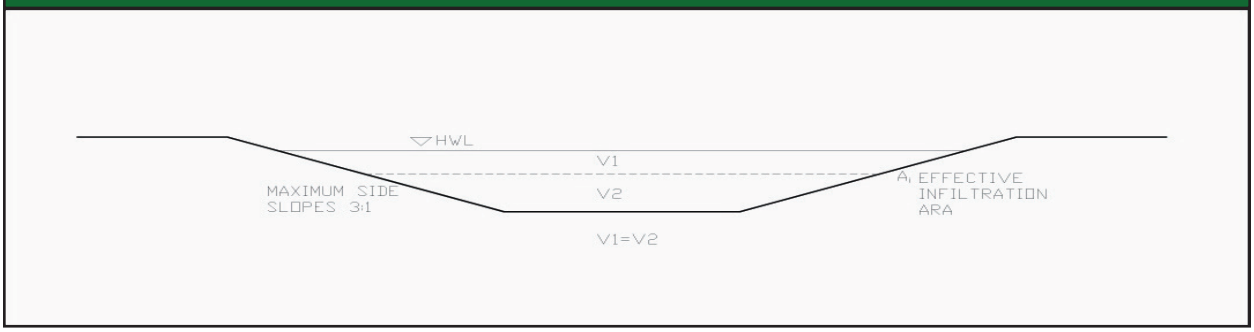
For underground practices (e.g. infiltration trenches, dry wells, subsurface infiltration practices)

$A_i = V_w/nD$

Where:

A_i	=	effective infiltration area is the sum of the bottom area and the sides of the practice* (ft^2)

Figure 8.11 Effective infiltration area for above ground practices with side slopes that are 3:1 or shallower



V_w	=	design volume (e.g. VCS) (ft^3)
n	=	porosity of filter media (range of porosity values for sands and gravels: 0.25 to 0.5)
D	=	maximum depth of practice (feet) Note: *maximum of 12 feet, and separated by at least three feet from seasonally high groundwater table*

For subsurface infiltration practices, use the procedure described above or technique recommended by manufacturer.

* Since underground facilities have potentially more surface area in contact with permeable soils, these practices should take these areas into consideration. Only that portion of the sides that is in contact with naturally permeable material should be used in calculating the effective infiltration area of the practice.

► ***Volume*** – The preliminary volume of the infiltration practice is determined by multiplying the average

basin area by the depth of the practice.

$V = A \times D$ *Total Storage Volume for Infiltration Basins and Underground Infiltration Systems*

Where:

V	=	Design volume for infiltration basin and underground infiltration system
A	=	average basin area (square feet)
D	=	depth of practice (feet)

For those practices that do not involve a media filter (e.g. infiltration basin and underground infiltration systems) this volume represents the total storage volume (design volume) of the practice. For those practices which do involve a media filter (e.g. infiltration trenches and dry wells) this volume represents the void space and the total storage volume will be greater. The following formula can be used to determine the total storage volume (design volume):

$V_T = A \times n \times D_i$ *Total Storage Volume for Infiltration Trenches and Dry Wells*

Where:

V_T	=	Design volume for infiltration trenches and dry wells (cubic feet)
A	=	average basin area (square feet)
n	=	porosity of filter media (range of porosity values for sands and gravels: 0.25 to 0.5)
D	=	depth of practice (feet)

Step 7. Size outlet structure and/or flow diversion structure, if needed (Note: Steps 5, 6, 7 and 8 are iterative)

It is HIGHLY RECOMMENDED that the outlet for the infiltration practice shall safely convey stormwater using all of the following mechanisms (Infiltration Basin, Wisconsin Department of Natural Resources Conservation Practice Standard 10/04).

- ***Drawdown valve*** – Infiltration basins may be designed with a draw down valve for the removal of standing water for maintenance and winter diversion.
- ***Emergency spillway*** – A means to release discharge in excess of the infiltration volume safely into the downstream stormwater conveyance system is REQUIRED.
- ***Freeboard*** – It is HIGHLY RECOMMENDED that two feet of freeboard be provided from the 100-year flood elevation of the infiltration practice to the lowest basement floor elevation of residential, commercial, industrial and institutional buildings located adjacent to the BMP, unless local requirements recommend otherwise.
- ***Drop Structure*** – Infiltration trenches or subsurface infiltration systems may be designed with a drop structure sized to handle the overflow. This additional volume of stormwater may be directed into the existing stormwater system or it may be diverted to a downstream BMP.

Step 8. Check volume, peak discharge rates and period of inundation against State, local and Watershed Management Organization requirements (Note: Steps 5, 6, 7 and 8 are iterative)

Follow the design procedures identified in the Unified Sizing Criteria section of the Manual to determine the volume control and peak discharge requirements.

Perform hand calculations or model the proposed development scenario using a surface water model

appropriate for the hydrologic and hydraulic design considerations specific to the site (see also Chapter 7 and 9 of the manual). This includes defining the parameters of the infiltration practice defined above: elevation and area (defines the storage volume), infiltration rate and method of application (effective infiltration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated (back to Step 5).

The following items are specifically REQUIRED by the NWA Planned Unit Development, Inver Grove Heights City Code, or the MPCA Permit:

- *Recharge* ***Volume*** –The recharge volume is determined by taking the difference between the pre-development volume for the 5-year 24-hour event and the post-development volume for the same event. Recharge can be achieved either by a structural BMP (e.g. infiltration, bioretention, vegetated swale), better site design techniques, or a combination of both. If this criterion is not met, increase the storage volume of the infiltration practice or treat excess water quality volume (VCS) in an upstream or downstream BMP (see Step 5).
- ***Peak Discharge Rates*** – The intent of this sizing criterion is two-fold: controlling peak discharge for the 2-year 24-hour event prevents habitat degradation and erosion in urban streams (open ditch fl ow) and controlling peak discharge for the 10- and 100-year 24-hour events prevents flood damage to conveyance systems and infrastructure and reduces minor flooding caused by overbank floods.
- ***Period of Inundation*** – Infiltration practices shall discharge through the soil or filter media in 72 hours or less (48 hours if the practice is designed to meet the MPCA General Construction Permit). Additional flows that cannot be infiltrated or filtered in 72 hours should be routed to bypass the system through a stabilized discharge point. This criterion was established to provide the following: wet-dry cycling between rainfall events; unsuitable mosquito breeding habitat; suitable habitat for vegetation; aerobic conditions; and storage for back-to-back precipitation events. The period of inundation is defined as the time from the high water level in the practice to 3 to 6 inches above the invert of the outlet structure or drain tile or bottom of the facility. It is assumed that this range is less than 1/5 the bounce in the infiltration practice.

Other design requirements may apply to a particular site. The applicant should confirm local design criteria and applicability (see Step 3).

Step 9. Perform groundwater mounding analysis (Note: Steps 5, 6, 7 and 8 are iterative)

Ground water mounding, the process by which a mound forms on the water table as a result of recharge at the surface, can be a limiting factor in the design and performance of infiltration practices. A minimum of 3 feet of separation between the bottom of the infiltration practice and the seasonally high water table is REQUIRED (5 feet HIGHLY RECOMMENDED) to maintain the hydraulic capacity of the practice and provide adequate water quality treatment.

The most widely known and accepted analytical methods to solve for ground water mounding are based on the work by Hantush (1967) and Glover (1960). The maximum ground water mounding potential should be determined through the use of available analytical and numerical methods. Detailed ground water mounding analysis should be conducted by a trained hydrogeologist or equivalent as part of the site design procedure.

Step 10. Determine pretreatment volume and design pretreatment measures

See the section on pretreatment earlier in this section and Chapter 7 for specific pretreatment design guidance.

F. Links to Other Manuals

Georgia Stormwater Management Manual. 2001. Atlanta Regional Commission.
http://www.georgiastormwater.com/

Vermont Stormwater Management Manual. 2002.
http://www.vtwaterquality.org/stormwater.htm.

Wisconsin DNR Site Evaluation for Stormwater Infiltration Conservation Practice Standard 1002. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

Wisconsin DNR Infiltration Basin Conservation Practice Standard 1003. 2004.
http://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm#Post.

G. References

Bouwer, H. and R. C. Rice. 1989. Effect of Water Depth in Groundwater Recharge Basins on Infiltration. Journal of Irrigation and Drainage Engineering, Vol. 115, No. 4, pp. 556-567.

Georgia Stormwater Management Manual. 2001.

Glover, R., 1960. Mathematical Derivations as Pertain to Ground-water Recharge. Report CER60REG70. Agricultural Research Service, USDA, Fort Collins, Colorado. 81 pp.

Hantush, M., 1967. Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation. Water Resources Research, 3(1): 227-234.

Rawls, W., D. Brakensiek, and K. Saxton, 1982. Estimation of Soil Water Properties, Transactions of the American Society of Agricultural Engineers. Vol. 25, No. 5, pp. 1316 – 1320 and 1328.

Rawls, W., D. Giminez, and R. Grossman, 1998. Use of Soil Texture, Bulk Density and Slope of water Retention Curve to Predict Saturated Hydraulic Conductivity, ASAE. Vol. 41(4), pp. 983 – 988.

Metropolitan Council Urban Small Sites Best Management Practice Manual. 2001.

Minnesota Pollution Control Agency Stormwater Best Management Practices Manual. 2000.

Natural Resources Conservation Service, 1986. Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55). ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf

South Washington Watershed District (SWWD), 2005. 2004 Infiltration Monitoring Program Final Report. Emmons and Olivier Resources, Inc.

United States Department of Agriculture Natural Resources Conservation Service. TR-55, Urban Hydrology for Small Watersheds. Washington D.C., 1975.

U.S. Environmental Protection Agency, When are Storm Water Discharges Regulated as Class V Wells, June 2003

University of Wisconsin – Extension Wisconsin Storm Water Manual: Technical Design Guidelines for Storm Water Management Practices. 2000.

Winer, R. 2000. National Pollutant Removal Performance Database.

STORMWATER PONDS



Stillwater, MN

Definition:
A constructed basin situated to receive local stormwater runoff and hold designated volumes of runoff for specified periods of time. The objectives are to improve water quality through settling and biological uptake, and prevent downstream channel degradation or flood damage through storage and outflow rate reduction.

KEY CONSIDERATIONS

Design Criteria (for new construction):

- Irregularly shaped with minimum length to width ratio of 1.5:1
- Permanent pool volume of 1800 cubic feet per acre draining to pond.
- Permanent pool depth 3' minimum, 10' maximum at deepest points
- Extended detention (ED) storage sufficient to treat V_{wq}
- Pre-treatment required (sediment forebay sized at 10% of pond area recommended)
- Stabilized emergency overflow and energy dissipation at all outlets
- Side slopes not to exceed 1V:3H

Benefits:

- Able to effectively reduce many pollutant loads and control runoff flow rates
- Relatively straightforward design procedure
- Potential wildlife habitat and aesthetic or recreational enhancement
- May be used as temporary sedimentation basin during construction

Limitations:

- Relatively large space requirement
- Tends to increase water temperature and may cause downstream thermal impact
- Potential for nuisance insects or odor
- Problematic for areas of low relief, high water table, or near-surface bedrock
- Possible safety concerns

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
	Screening/ Filtration
	Temperature Control
X	Settling
X	Evaporation
	Transpiration
	Soil Adsorption (limited)
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

80%	Total Suspended Solids
40%/30%	Nutrients - Total Phosphorus/ Total Nitrogen
60%	Metals - Cadmium, Copper, Lead, and Zinc
70%	Pathogens - Coliform, Streptococci, E. Coli
80%	Toxins - Chloride, Hydrocarbon, Pesticide

STORMWATER PONDS

SITE FACTORS

25 AC Min*	Drainage Area *10 AC possible if hydrology capable of supporting water levels
25%	Max. Site Slope
0*	Min. Depth to Bedrock *2 ft in PSH areas
0*	Min. Depth to Seasonally High Water Table *pond bottom must be above bedrock
C,D Preferred	NRCS Soil Type *A and B soils require liners
Poor*	Freeze/ Thaw Suitability *unless adapted with additional storage for snowmelt
Yes	Potential Hotspot Runoff *requires impermeable liner

Description:

Stormwater ponds are constructed basins placed in the landscape to capture stormwater runoff. The pond is graded and outlet structures are designed in such a way that specified volumes of water are either held until displaced by future runoff or detained for a specified period of time. While the runoff is being held in the pond, sediment and associated pollutants settle to the bottom. Pollutants can also be removed from the stormwater through microbial, plant and algal biological uptake.

Storage in a stormwater pond can be either permanent pool or extended detention storage. As the name implies, water in the permanent pool is meant to remain in the basin, allowing settling and biological uptake to occur between storms and protecting against sediment resuspension. To maintain a permanent pool over a period of time, the pond must be designed with a sufficiently large drainage area. Extended detention storage refers to the volume above the permanent pool which is controlled by an outlet structure, sized so that runoff from larger storms can be captured and released over a period of time, allowing some settling to occur and keeping flow rates in check.

Sediment and pollutant removal in stormwater ponds can be enhanced through the use of multiple cells in succession. In particular, a sediment forebay (pre-treatment basin) sized at 10% of the pond area should be considered upstream of the pond. This allows for settling of heavier materials in a designated area, enhancing the main pond performance and reducing the maintenance burden by concentrating the majority of sediments in one location.

It is also possible to design a pond with no extended detention storage (wet pond), in which the only outlet is the spillway and where 100% of the treated volume is within the permanent pool. When a storm occurs, the treated runoff in the pond is displaced by new (untreated) runoff. Wet ponds are able to fulfill water quality treatment requirements, but do not mitigate the channel degradation or flooding effects of increased flow from larger storms. Also, wet ponds are not generally recommended for cold climates because during frozen conditions, runoff can flow over the ice of the permanent pool, effectively negating the benefits of the intended treatment volume. Generally the most desirable pond configuration for Minnesota is a large enough permanent pool to meet water quality needs, and sufficient extended detention to ensure adequate treatment during frozen conditions.

A. Suitability

General

Generally speaking, the term “stormwater pond” may refer to any constructed basin that is built for the purpose of capturing and storing stormwater runoff, either temporarily or for an extended period of time, in order to prevent or mitigate downstream water quantity or quality impacts. Several distinct structure types (wet ponds, dry ponds, etc.) are included in this general category, and they are discussed in more detail below.

Function Within Stormwater Treatment Train

Stormwater ponds are typically installed as an end-of-pipe BMP at the downstream end of the treatment train. The use of stormwater ponds in Inver Grove Heights will regularly be for pretreatment prior to reaching an infiltration practice. At first this may seem as though it is requiring double the amount of stormwater treatment, while in reality this system is analogous to treating water with a stormwater pond and then discharging it to a surface water body. The pond is the same and the infiltration practice acts as the pipe that would normally take stormwater off-site. Stormwater pond size and outflow regulation requirements can be significantly reduced with the use of additional upstream BMPs.

Inver Grove Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights’ Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Ponds generally may be used to meet the Inver Grove Heights pretreatment requirements. Stormwater ponding systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Several distinct pond design variants are typically described in current stormwater management literature. While it is possible that any one of these pond types could be beneficially implemented somewhere in Inver Grove Heights, both the climatic conditions and the applicable regulations prevalent throughout the state strongly favor the use of one of them in particular, namely the wet extended detention pond. For this reason, much of the discussion in this chapter is focused primarily on wet extended detention ponds; however, all four main design variants are presented here for the sake of completeness.

1. ***Flow-through pond (no extended detention)***. Often called a “wet pond” in other literature, a pond that has an essentially unrestricted spillway as its primary outlet, with its crest at the elevation of the permanent pool. Provides water quality treatment by holding a volume of

stormwater equal to the permanent pool volume, permitting settling to occur. The water stored in the pond is later displaced by new runoff. The flow-through pond is generally not a good design option for Minnesota, because the storage volume allocated for treatment is entirely below the permanent pool, making it inaccessible to new runoff during frozen conditions (cold climate considerations are discussed in more detail below)

2. ***Wet extended detention pond.*** Indicates a combination of permanent pool storage and extended detention storage above the permanent pool to provide additional water quality or rate control.
3. ***Micropool extended detention pond***. Variation of the wet extended detention pond with a markedly smaller permanent pool at the pond outlet to prevent resuspension.
4. ***Dry pond.*** No permanent pool; relies only upon extended detention storage for its treatment volume. Highly susceptible to sediment resuspension and generally only useful for rate control.

Retrofit Suitability

Ponds are widely used for stormwater retrofits, and have two primary applications as a retrofit design. In communities where dry detention ponds were designed for flood control in the past, these facilities can be modified by adding a permanent wet pool for water quality treatment and adapting the outlet structure for channel protection. Alternatively, new ponds can be installed in available open areas as a part of a comprehensive watershed retrofit inventory.

Cold Climate Suitability

One of the biggest problems associated with proper pond operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the CWP (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Increase the slope of inlet pipes to a minimum of 1% to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½”. In addition, the pipe should have a minimum 6” diameter.
- When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6" below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water quality events. This practice was both avoids stream warming and is also a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation.

Water Quantity Treatment

Stormwater ponds are one of the best and most cost-effective methods for providing rate control which will require evaluation to meet the wetland bounce and duration standards. These goals are achieved with the use of extended detention storage, where runoff is stored above the permanent pool and released at a specified rate through a control structure. Depending upon the soil types, the stormwater pond can be

designed to provide volume control through the sides of the basin above the normal water level. Wherever an embankment is constructed to store water at a level higher than the surrounding landscape, dam safety regulations must be followed to ensure that downstream property and structures are adequately protected.

Water Quality Treatment

Ponds rely on physical, biological, and chemical processes to remove pollutants from incoming stormwater runoff. The primary treatment mechanism is gravitational settling of particulates and their associated pollutants as stormwater runoff resides in the pond. Another mechanism for the removal of pollutants (particularly nutrients) is uptake by algae and aquatic vegetation. Volatilization and chemical activity can also occur, breaking down and assimilating a number of other stormwater contaminants such as hydrocarbons.

The longer the runoff remains in the pond, the more settling (and associated pollutant removal) and other treatment can occur, and after the particulates reach the bottom of the pond, the permanent pool protects them from resuspension when additional runoff enters the basin. For these reasons, because they lack the crucial permanent pool, **dry extended detention ponds are not considered an acceptable option for meeting pretreatment goals.**

Removal efficiencies for key pollutants for wet / wet extended detention ponds are provided in Table 8.35.

Table 8.35 Reported Percent Removal of Key Pollutants

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Wet Extended Detention Pond	80	50	30	60	70	80[2]

Notes:
1. Average of zinc and copper.
2. Based on fewer than five data points (i.e., independent monitoring studies)

Removals represent median values from Winer (2000) and have been rounded.

Typical effluent concentrations for selected water quality parameters are provided in Table 8.36.

Table 8.36 Typical BMP Effluent Concentrations

Practice	TSS [mg/l]	TP [mg/l]	TN [mg/l]	Cu [ug/l]	Zn [ug/l]
Wet Extended Detention Pond	10[1]	0.2[1]	1.3[2]	5.0[1]	30[1]

Values from (1) ASCE bmp database and (2) Winer 2000 (shaded values)

Limitations

The following general limitations should be recognized when considering installation of stormwater ponds:

- they consume a large amount of space
- they tend to increase water temperature and may cause downstream thermal impact

- they have the potential for nuisance insects or odor
- they are problematic for areas of low relief, high water table, or near-surface bedrock
- they pose safety concerns

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to use a pond for stormwater management, it is helpful to consider several items that bear on the feasibility of using a pond at a given location. The following list of considerations will help in making an initial judgment as to whether or not a pond is the appropriate BMP for the site.

- ***Drainage Area*** – 25 acres minimum HIGHLY RECOMMENDED, to ensure hydrologic input sufficient to maintain permanent pool; 10 acres (or less) may be acceptable, particularly if the groundwater table is intercepted and a water balance indicates that a permanent pool can be sustained.
- ***Space Required*** – Approximately 1-3% of the tributary drainage area is RECOMMENDED for the pond footprint.
- ***Site Topography and Slope*** – It is HIGHLY RECOMMENDED that slopes immediately adjacent to ponds be less than 25% but greater than 0.5 – 1% to promote flow towards the pond.
- ***Minimum Head*** – The elevation difference RECOMMENDED at a site from the inflow to the outflow is 6-10 feet.
- ***Minimum Depth to Water Table*** – In general, there is no minimum separation distance required with ponds. Intercepting the groundwater table can help sustain a permanent pool. However, some source water protection requirements may dictate a separation distance or an impervious liner if there is a sensitive underlying aquifer and the bottom material of the pond allows for infiltration.
- ***Soils*** – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. A liner will likely be needed for most group “A” soils and some group “B” soils. A site specific geotechnical investigation should be performed. Also, if earthen embankments are to be constructed, it will be necessary to use suitable soils.
- ***Wetlands*** – It is REQUIRED that stormwater ponds not be located in jurisdictional wetlands.
- ***Groundwater Protection*** – It is HIGHLY RECOMMENDED that ponds treating runoff from PSHs provide excellent pretreatment capabilities. In some cases (depending on the land use and associated activities), lining the pond may be necessary to protect groundwater, particularly when the seasonally high groundwater elevation is within three feet of the pond bottom.
- ***Shallow Soils and Bedrock*** – Pond use is limited due to the available depth that may require shallow water depths, affecting the surface area required as well as the aesthetics of the pond. Consider a wetland as an alternative.

Conveyance

Inflow Points

- It is HIGHLY RECOMMENDED that a forebay be provided at each inlet contributing greater than 10% of the total design storm inflow to the pond, to reduce the future pond maintenance burden.
- It is HIGHLY RECOMMENDED that inlet areas be stabilized to ensure that non-erosive conditions exist during 10-year storms.
- It is HIGHLY RECOMMENDED that rip-rap or other channel liners be extended below the permanent pool elevation.
- It is HIGHLY RECOMMENDED that inlet pipe inverts be located at the permanent pool elevation. Submerging the inlet pipe can result in freezing and upstream damage (Figure 8.12).

- ► It is HIGHLY RECOMMENDED that inlet pipes have a slope of no flatter than 1%, to prevent standing water in the pipe and reduce the potential for ice formation.
- ► It is HIGHLY RECOMMENDED that pipes be buried below the frost line, to prevent frost heave and pipe freezing.
- ► It is HIGHLY RECOMMENDED that where open channels are used to convey runoff to the pond, the channels be stabilized to reduce the sediment loads.

Adequate Outfall Protection

- ► It is HIGHLY RECOMMENDED that a stilling basin or outlet protection be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps).
- ► Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement are RECOMMENDED over headwalls at the spillway outlet.
- ► It is RECOMMENDED that tree clearing be minimized along the downstream channel and that a forested riparian zone be reestablished in the shortest possible distance. It is also RECOMMENDED that excessive use of riprap be avoided, to minimize stream warming in channels with dry weather flow.
- ► Local agencies (Watershed Districts, Watershed Management Organizations (WMOs), municipalities, etc.) may have additional outlet control requirements.

Pretreatment

Construction of pretreatment measures immediately upstream of the main pond is HIGHLY RECOMMENDED, to reduce the maintenance requirements and increase the longevity of a stormwater treatment pond. A large portion of the overall sediment load (the heavier sediments) can be captured by relatively small (and therefore relatively easy to clean and maintain) BMPs. The larger pond area can thus be devoted to the settling of finer sediments, allowing it to fill more slowly and therefore requiring less frequent maintenance.

It is therefore HIGHLY RECOMMENDED that each pond have a sediment forebay or equivalent upstream pretreatment (non-pond BMPs may serve as pretreatment) at each inflow point that contributes greater than 10% of the inflow volume. A sediment forebay is a small pool, separated from the permanent pool by barriers such as earthen berms, concrete weirs, or gabion baskets, where initial settling of heavier particulates can occur.

- ► It is REQUIRED that where a forebay is installed, that direct vehicle/equipment access be provided to the forebay for sediment removal and other maintenance activities.
- ► It is HIGHLY RECOMMENDED that flows from forebays enter the permanent pool area with non-erosive outlet conditions.
- ► It is RECOMMENDED that the forebay(s) be sized to contain 10% of the volume control standard (VCS) in a pool that is four to six feet deep. The forebay storage volume counts toward the total permanent pool requirement.
- ► It is RECOMMENDED that the forebay(s) be designed with a surface area equivalent to 10% of the pond permanent pool surface area or equivalent to 0.1% of the drainage area.
- ► It is RECOMMENDED that a fixed vertical sediment depth marker be installed in the forebay to measure sediment deposition over time.
- ► It is RECOMMENDED that the bottom of the forebay be hardened, using concrete, asphalt, or grouted riprap, to make sediment removal easier.

Treatment

Permanent Pool and Volume Control Standard (VCS) Sizing

- ► Under the Inver Grove Heights Permit, it is REQUIRED that stormwater ponds designed for pretreatment to an infiltration area have permanent pool volume (dead storage) equal to at least 1800 cubic feet per acre of drainage to the pond. For example, a 30-acre drainage area requires a permanent pool volume of at least 54,000 cubic feet or 1.24 acre-feet.

- It is REQUIRED that permanent pool depths be a minimum of three feet and maximum of 10 feet at the deepest points. Where phosphorus load reductions are a priority, it is RECOMMENDED that a maximum depth of eight feet be used, to limit the likelihood of stratification and the potential for bottom sediment to release phosphorus.
- It is REQUIRED that the VCS be released at a rate not to exceed 5.66 cfs per acre of permanent pool surface area.
- Where phosphorus load reductions are a priority, permanent pool volumes as large as 3600 cubic feet per acre of drainage are RECOMMENDED for enhanced removal.
- A water balance is RECOMMENDED to document sufficient inflows to maintain a constant permanent pool during prolonged dry weather conditions.
- To compensate for ice build-up on the permanent pool, twelve inches of additional storage can be provided. This is an alternative to the preferred active management strategy of drawing down the permanent pool seasonally to provide detention while the permanent pool is frozen.
- Using pumps or bubbling systems can reduce ice build-up and prevent the formation of an anaerobic zone in pond bottoms. Caution must be exercised, however, because of the possibility of thin or no ice cover.

Pond Liners

It is HIGHLY RECOMMENDED that pond liners be considered in circumstances where a permanent pool is needed but difficult to maintain due to site conditions, or where seepage from the pond into the groundwater would otherwise occur but must be avoided. This includes:

- Areas with Hydrologic Group A soils, gravel, or fractured bedrock.
- Potential Stormwater Hotspots (PSHs)

If geotechnical tests confirm the need for a liner, acceptable options include: (a) six to 12 inches of clay soil, including bentonite, (minimum 15% passing the #200 sieve and a maximum permeability of 1 x 10^{-5} cm/sec), (b) a 30 ml poly-liner, or (c) engineering design as approved on a case-by-case basis by Inver Grove Heights city engineer.

Grading and Site Layout

The site layout and pond grading affect the pollutant removal capability of the pond as well as the ease of maintenance. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flowpaths, high surface area to volume ratios, complex microtopography, and/or redundant treatment methods (combinations of pool, ED, and marsh). It is RECOMMENDED that a berm or simple weir be used instead of pipes to separate multiple ponds, because of the higher freezing potential of pipes. Specific guidelines are provided below:

- It is HIGHLY RECOMMENDED that pond side slopes within the permanent pool (below the aquatic bench) not exceed 2:1 (H:V).
- It is HIGHLY RECOMMENDED that side slopes to the pond should be 3:1 or flatter, and that they terminate on a safety bench (see next section).
- It is RECOMMENDED that approximately 15% of the permanent pool surface area be allocated to a shallow (i.e., less than or equal to 18” in depth) zone along the perimeter to promote a shallow marsh littoral zone.
- It is RECOMMENDED that the minimum length to width ratio for ponds be 1.5:1.
- It is RECOMMENDED that the maximum drainage area to surface area ration be 100:1.
- It is RECOMMENDED that to the greatest extent possible, ponds should be irregularly shaped and long flow paths should be maintained.

Pond Benches

All pond designs should incorporate an access bench (a shallow slope area adjacent to the pond, preventing people from slipping into the water) and a submerged aquatic bench (a shallow slope area just inside the pond perimeter, facilitating the growth of aquatic plants).

- Safety Bench: It is HIGHLY RECOMMENDED that an access bench extending 10 feet outward from the permanent pool edge to the toe of the pond side slope be provided. Narrower benches may be used on sites with extreme site limitations. The maximum cross-slope of the safety bench should be 6%. Safety benches are not needed when the pond side slopes are 4:1 or flatter.
- Aquatic Bench: It is HIGHLY RECOMMENDED that an irregularly configured aquatic bench, extending up to 10 feet inward from the normal shoreline and graded no more than eighteen inches below the permanent pool water surface elevation, be incorporated into the pond.

Maintenance Access

- It is REQUIRED that adequate maintenance access be provided. It is HIGHLY RECOMMENDED that the access be at least 12 feet wide, have a maximum slope of 15%, and be appropriately stabilized for use by maintenance equipment and vehicles. Steeper grades may be allowable if designed using appropriate materials for the grade.
- It is REQUIRED that the maintenance access extend to the forebay, safety bench, riser, and outlet, and allow vehicles to turn around.

Riser in Embankment

- It is REQUIRED that the riser be located so that short-circuiting between inflow points and the riser does not occur.
- It is RECOMMENDED that the riser be located within the embankment for maintenance access, prevention of ice damage, and aesthetics.

Spillway Design

The principle spillway (riser) should be designed for the desired release rates while keeping the future maintenance needs in mind. Lessening the potential for clogging and freezing, creating safe access paths for inspection and maintenance, barring access to children and vandals, and allowing safe draw down of the permanent pool when necessary are goals of riser design that consider long-term maintenance needs.

Non-clogging Low Flow Orifice

- It is HIGHLY RECOMMENDED that the low flow orifice be adequately protected from clogging by either an acceptable external trash rack (recommended minimum orifice of 3") or by internal orifice protection that may allow for smaller diameters (recommended minimum orifice of 1"). Appendix A contains design details for both low flow orifice protection options.
- The RECOMMENDED method is a submerged reverse-slope pipe that extends downward from the riser to an inflow point at least one foot below the normal pool elevation (see Appendix A for a typical detail). This should also draw from at least 6” below the typical ice layer, but to avoid sediment deposition, the pipe should not be installed on the pond floor
- Alternative methods are to employ a broad crested rectangular, V-notch, or proportional weir, protected by a half-round CMP that extends at least 12 inches below the normal pool. It is HIGHLY RECOMMENDED that the minimum weir slot width be 3”, especially when the slot is tall. It is RECOMMENDED that hoods over orifices be oversized to account for ice formation.

Trash Racks

- It is REQUIRED that basin outlets be designed to prevent discharge of floating debris. It is HIGHLY RECOMMENDED that the principal spillway openings be equipped with removable trash racks to prevent clogging by large debris and to restrict access to the interior for safety purposes. Recommended openings are 8 inches.
- It is RECOMMENDED that trash racks be installed at a shallow (~15°) angle to prevent ice formation.
- Baffle weirs (essentially fences in the pond) can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.

Pond Drain

It is HIGHLY RECOMMENDED that each pond be equipped with a drain that can dewater the pond to the maximum extent possible within 24 hours. The drain pipe should have an elbow or protected intake extending at least 12" above the bottom of the permanent pool to prevent deposited sediment from clogging the pipe.

Adjustable Gate Valve

- It is RECOMMENDED that the pond drain and possibly the low flow orifice be equipped with an adjustable gate valve (typically a handwheel activated knife gate valve). These valves should be located inside the riser, where they (a) will not normally be inundated and (b) can be operated in a safe manner. To prevent vandalism that alters the pond level, the handwheel should be chained to a ringbolt, manhole step or other fixed object.
- It is RECOMMENDED that both the low flow orifice pipe and the pond drain be sized one pipe size greater than the calculated design diameter and the gate valve used to adjust the opening to an equivalent diameter.

Riser Access

It is RECOMMENDED that lockable manhole covers and manhole steps within easy reach of valves and other controls be installed, to allow for inspector access and prevent vandalism.

Emergency Spillway

It is REQUIRED that an emergency spillway should be provided to pass storms in excess of the pond hydraulic design. It is also REQUIRED that the spillway be stabilized to prevent erosion and designed in accordance with applicable dam safety requirements (NRCS Pond Standard 378 and MnDNR dam safety guidelines). The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges. If the spillway crosses the maintenance access, materials meeting the appropriate load requirements must be selected.

Landscaping

Landscaping Plan

It is HIGHLY RECOMMENDED that a landscaping plan for the stormwater pond and the surrounding area be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation (see Appendix B for detailed guidance). The following guidance suggests how landscaping can be incorporated into pond design.

- Woody vegetation should not be planted or allowed to grow within 15 feet of the toe of the embankment or 25 feet from the inlet and outlet structures.
- Wherever possible, wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the access bench and side slopes (ED wetlands) or within shallow areas of the pool itself.
- The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.
- The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils can be so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil or other organic material (see bioretention specifications).
- As a rule of thumb, planting holes should be three times deeper and wider than the diameter of the rootball (of balled and burlap stock), and five times deeper and wider for container grown stock. This practice should enable the stock to develop unconfined root systems.
- Species that require full shade, are susceptible to winterkill, or are prone to wind damage should be avoided. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

Pond Buffers and Setbacks

- It is REQUIRED (Minnesota Department of Health Rule 4725.4350) that a 50' setback between stormwater ponds and water supply wells be provided.
- It is HIGHLY RECOMMENDED that a pond buffer extending 25 feet outward from the maximum water surface elevation of the pond be provided. Permanent structures (e.g., buildings) should not be constructed within the buffer. This distance may be greater under local regulations.
- The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers).
- It is HIGHLY RECOMMENDED that existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To help discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.

Safety

- It is REQUIRED that public safety be considered in every aspect of pond design.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.
- The access and aquatic benches should be landscaped to prevent access to the pond.
- Warning signs prohibiting swimming, skating, and fishing should be posted.
- Pond fencing is generally not encouraged. A preferred method is to grade the pond to eliminate steep drop-offs or other safety hazards.
- Dam safety regulations should be strictly followed with pond design to ensure that downstream property and structures are adequately protected.

C. Construction Details and Specifications

CADD based details for pond systems are contained in Appendix A. The following details, with specifications, have been created for stormwater ponds:

- Stormwater pond plan
- Stormwater pond profile
- Pond inlet
- Riser pipe outlet structure

D. Operation and Maintenance

Overview

Maintenance is necessary for a stormwater pond to operate as designed on a long-term basis. The pollutant removal capabilities of ponds will decrease if:

- Permanent pool elevations fluctuate
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants out-compete the wetland plants
- Sediment accumulates in the pond, reducing the storage volume
- Slope stabilizing vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised.

Pond maintenance activities range in terms of the level of effort and expertise required to perform them. Routine pond and wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year. Owners may consider an "adopt-a-pond" program in which properly trained citizen volunteers perform basic landscape maintenance activities (the City of Plymouth, for example, has instituted such a program). More significant maintenance such as removing accumulated sediment is needed less frequently, but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) that has experience in the construction, inspection, and repair of these features.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections, many design elements of pond systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key maintenance considerations are providing access for inspection and maintenance, and designing all outlets and the principal spillway to minimize clogging. Providing easy access (typically 8 feet wide) to all pond components for routine maintenance is REQUIRED.

Stormwater ponds can be properly designed, constructed and maintained to minimize the likelihood of being desirable habitat for mosquito populations. Designs that incorporate constant inflows and outflows, habitat for natural predators, and constant permanent pool elevations limit the conditions typical of mosquito breeding habitat (see also Ch. 6 discussion on mosquito control).

Construction Phase Maintenance

The construction phase is another critical step where O&M issues can be minimized or avoided.

Inspections during construction are needed to ensure that the practice is built in accordance with the approved design standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post-Construction Operation and Maintenance

Operation to Address Frozen Conditions

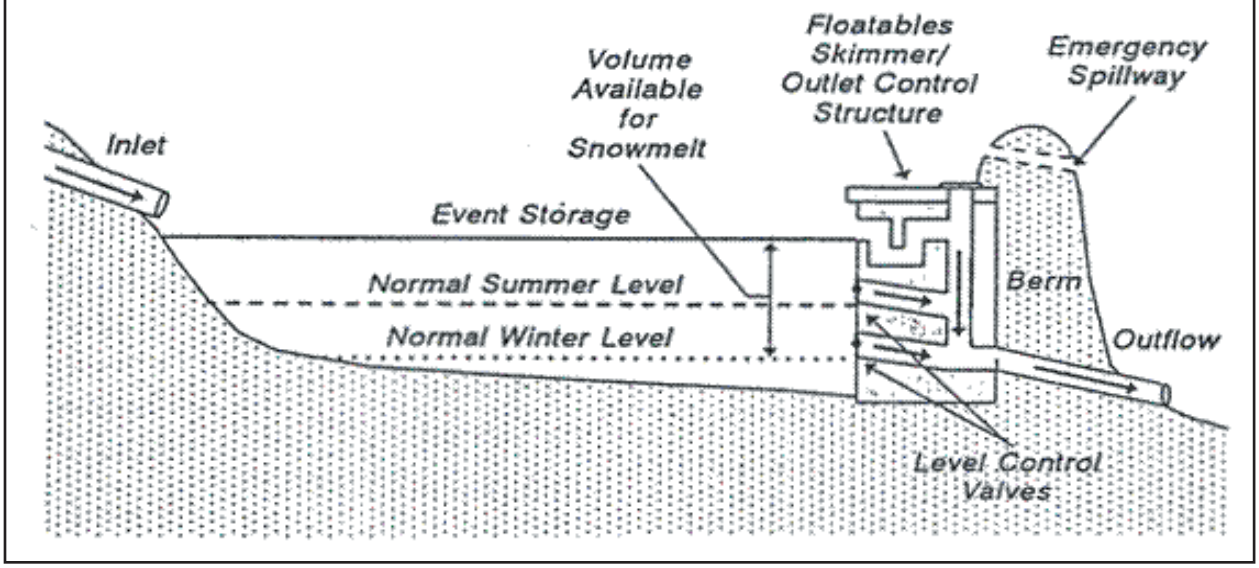
It is HIGHLY RECOMMENDED that the O&M plan include a provision to lower the level of the permanent pool in the late fall, to provide additional retention storage for snowmelt runoff and ensure that some permanent pool storage is available above the ice (as Figure 8.12 illustrates, the permanent pool should not be completely eliminated nor allowed to freeze through completely).

Maintenance

Some important post construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix F. More detailed maintenance guidance can be found in the Pond and Wetland Maintenance Guidebook (CWP, 2004).

- ► It is REQUIRED that a legally binding and enforceable maintenance agreement be executed between the practice owner and the local review authority.
- ► Adequate access must be provided for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles. It is RECOMMENDED that a maintenance right of way or easement extend to ponds from a public or private road.
- ► It is HIGHLY RECOMMENDED that ponds be inspected annually during winter freeze periods to look for signs of improper operation.

Figure 8.12 Frozen condition pond outlet



- ► It is HIGHLY RECOMMENDED that sediment removal in the forebay occur every 2 to 7 years or after 50% of total forebay capacity has been lost. In areas where road sand is used, an inspection of the forebay and stormwater wetland should be scheduled after the spring melt to determine if clean-out is necessary.
- ► Sediments excavated from stormwater ponds that do not receive runoff from confirmed hotspots are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be necessary prior to sediment disposal when a confirmed hotspot land use is present.
- ► Periodic mowing of the pond buffer is HIGHLY RECOMMENDED along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year), prairie, or forest.
- ► Ponds should not be drained during the spring, as temperature stratification and high chloride concentrations at the bottom can occur, which could result in negative downstream effects.
- ► Care should be exercised while draining the pond to prevent rapid release and minimize the discharge of sediments or anoxic water. The approving jurisdiction should be notified before draining a pond.
- ► It is REQUIRED that OSHA safety procedures be followed for maintenance activities within enclosed areas, such as outlet structures.

General maintenance activities and schedule are provided in Table 8.37.

Table 8.37 Typical Inspection/Maintenance Frequencies for Ponds		
Inspection Items	**Maintenance Items**	**Frequency**
► Ensure that at least 50% of wetland plants survive ► Check for invasive wetland plants	► Replant wetland vegetation	One time - After First Year
► Check that maintenance access is free and clear ► Inspect low flow orifices, reverse flow pipes, and other pipes for clogging ► Check the permanent pool or dry pond area for floating debris, undesirable vegetation ► Investigate the shoreline for erosion ► Monitor wetland plant composition and health ► Look for broken signs, locks, and other dangerous items.	► Mowing – minimum Spring and Fall ► Remove debris ► Repair undercut, eroded, and bare soil areas	Monthly to Quarterly or After Major Storms (>1")
► Monitor wetland plant composition and health ► Identify invasive plants ► Ensure mechanical components are functional	► Trash and debris clean-up day ► Remove invasive plants ► Harvest wetland plants ► Replant wetland vegetation ► Repair broken mechanical components if needed	Semi-annual to annual
► All routine inspection items above ► Inspect riser, barrel, and embankment for damage ► Inspect all pipes ► Monitor sediment deposition in facility and forebay	► Pipe and Riser Repair ► Forebay maintenance and sediment removal when needed	Every 1 to 3 years
► Monitor sediment deposition in facility and forebay	► Forebay maintenance and sediment removal when needed	2-7 years
► Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping	► Sediment removal from main pond/wetland ► Pipe replacement if needed	5-25 years

Cost Considerations

Costs for ponds typically include costs for embankment, riser and spillway structures, outfall protection, vegetative stabilization, excavation, and grading. Additional costs for site preparation can include soil amendments, precision grading, plant materials and creation of occluding layers in coarse-textured soil types if wetlands systems must be created on upland sites due to project constraints. Project costs can be lowered if existing pre-construction site conditions are carefully considered and isolated areas with hydric soils contained within the footprint of the project are utilized as stormwater management facilities.

Additional maintenance costs will be incurred until the establishment of the wetland ecosystem. Invasive plants must be culled and dead plants replaced. The outlet structure may have to be adjusted, based on seasonal observations, to achieve the proper water surface in the pond.

Construction and Maintenance Costs

Utilizing Table 8.38 and the cost estimation worksheet in Appendix F, will allow designers to avoid over or under estimation of fixed costs.

Table 8.38 lists the specific site components that are specific to stormwater ponds. Not included in this table are those cost items that are common to all construction projects, such as mobilization, traffic control, erosion and sediment control, permitting, etc. A more detailed worksheet, utilizing 2005 construction prices, is contained in Appendix F.

Table 8.38 Cost Components for Stormwater Ponds

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	8-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Inlet structure	($/structure)	Pipes, catchbasins, manholes, valves
	Outlet structure	($/structure)	
Site Restoration	Seeding or sodding	Seeding Cost ($/acre) x Seeded Area (acre)	Tree protection, soil amendments, seed bed preparation, trails
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2 / 1yr)	Vegetation maintenance, cleaning of structures
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1 / 5yr)	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2 / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (2 / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4 / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for a wet extended detention pond (wet sedimentation basin) in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Design Steps

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a stormwater pond, and identify the function of the pond in the overall treatment system

A. Consider basic issues for initial suitability screening

- ► Site drainage area
- ► Depth to water table
- ► Depth to bedrock
- ► Presence of wetlands
- ► Soil characteristics
- ► Receiving water(s)

B. Determine how the pond will fit into the overall stormwater treatment system.

- ► In Inver Grove Heights, stormwater ponds will generally be used for pretreatment upstream of an infiltration practice.
- ► Determine whether the pond needs to treat the volume control standard (VCS)
- ► Determine whether the pond is being designed as a wet detention pond under the MPCA General Stormwater Permit for Construction Activities.
- ► Determine whether the pond will be used as a temporary sediment basin during construction.
- ► Decide where on the site the pond is most likely to be located.

Step 2. Confirm design criteria and applicability.

A. Determine whether the pond must comply with the MPCA Permit.
B. Check with Inver Grove Heights officials, WMOs, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Confirm site suitability

A. Perform field verification of site suitability.

- ► If the initial evaluation indicates that a pond would be a good BMP for the site, it is RECOMMENDED that a minimum of three soil borings or pits be dug in the same location as the proposed pond to verify soil types and to determine the depth to groundwater and bedrock.
- ► It is RECOMMENDED that the minimum depth of the soil borings or pits be five feet below the bottom elevation of the proposed pond.
- ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

B. Perform water balance calculations if needed.

Step 4. Compute volume control standard (VCS) and permanent pool volume.

Refer to Chapter 7 for information on computing the volume control standard.

If the pond is being designed as a wet detention pond for new construction under the MPCA Permit, then a permanent pool volume equal to 1800 cubic feet for each acre draining to the pond is REQUIRED. This can be calculated as:

$$\text{Permanent Pond Volume} = 1800 \left[\frac{ft^3}{Ac}\right] * A\,[Ac]\ [ft3]$$



If the pond will be used for temporary sediment control during construction, the associated permanent pool volume REQUIRED is either the 2 year, 24 hour storm runoff volume draining to the pond (with minimum 1800 cubic feet for each acre draining to the basin), or in the absence of such a calculation, 3600 cubic feet for each acre draining to the basin. It is also REQUIRED that sediment deposited during construction be removed before normal operation begins (refer to MPCA Permit for additional design requirements).

If part of the overall VCS is to be treated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be treated by the pond. It is assumed that the pond will be the only BMP used for rate control for larger storms.

Details on the Stormwater Sizing Criteria are found in Chapter 7.

Step 5. Determine pretreatment (sediment forebay) volume (HIGHLY RECOMMENDED).

In the absence of adequate upstream treatment by other BMPs, it is HIGHLY RECOMMENDED that a sediment forebay or similarly effective pretreatment system be provided at each inlet providing 10% or more of the total design inflow, with a RECOMMENDED volume equal to 10% of the permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool requirement. Likewise, the storage volumes from other BMPs used upstream in the treatment train count toward the total permanent pool requirement and thus may be subtracted.

Step 6. Consider volume control standard variations for frozen conditions (HIGHLY RECOMMENDED).

When the pond and sediment forebay are frozen, much of the storage is rendered ineffective because stormwater runoff can flow over the ice and bypass the intended treatment. To alleviate this problem, additional extended detention storage (which is available even under frozen conditions) can be designed into the pond by increasing the extended detention storage volume designated for water quality control, or by adding a weir structure to the sediment forebay overflow area.

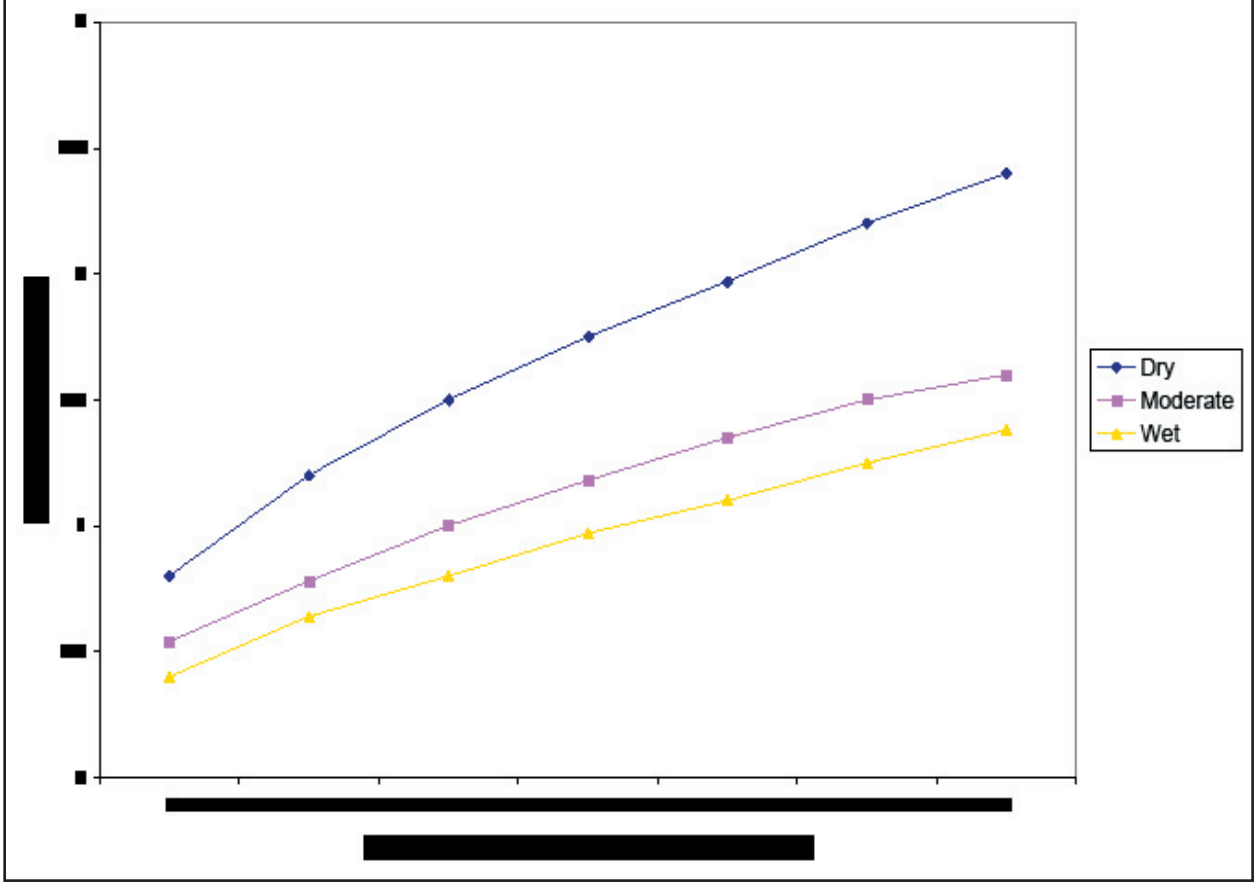
The average snowmelt volume can be computed from the following equation:

Average snowmelt volume (depth/unit area)	=	Average snowpack depth at the initiation of the snowmelt period	x	Typical snowpack water at time of melt	–	Estimated infiltration volume likely to occur during a 10-day melt period.

Table 8.38 and Figure 8.13 will allow the designer to determine both the average depth of snowpack existing at the start of spring snowmelt, plus the water content of the snowpack during the month of March.

Table 8.39 Snow Statistics for Inver Grove Heights	
Average Annual Snowfall	50 inches
Snow Depth at Initiation of Melt	7 inches (median snow depth on March 10)

Figure 8.13 Snowmelt Infiltration Based on Soil Moisture Content



Source: Adapted from Granger et al. 1984)

Snow Water Equivalent for March	0.12 (water inch / snow inch)

Source: Minnesota Climatology Working Group

Step 7. Determine location and preliminary geometry.

The preliminary grading plan can be developed with the following procedure:

1. Locate the pond in the lowest elevation area of the site (not in a jurisdictional wetland) and provide space around the pond for maintenance access. Adequate maintenance access is REQUIRED. 12' minimum width is HIGHLY RECOMMENDED.
2. Establish a primary outlet elevation (normal water level) and/or a pond bottom elevation.
3. Provide storage for the permanent pool below the primary outlet elevation in the main pond area.
4. Include an aquatic bench extending into the permanent pool and a access bench extending out

from the permanent pool.

5. Considering the desired pond footprint for the VCS and larger storms. While developing the grading plan, consider the desired (or required) length to width ratio and side slopes detailed earlier in this section (or in applicable regulations).
6. Once the preliminary grading plan has been developed, determine the associated stage-storage relationship for water surface elevations through the maximum expected levels.

The approximate storage corresponding to a given stage (elevation) can be determined using the average end area method. The area within each of the closed contour lines on the grading plan representing the pond is measured, and the average area of each set of adjacent contours is computed. The approximate volume between the two contours is then calculated as the average area multiplied by the elevation difference. Where V_{1-2} is the volume between contour 1 and contour 2, A_1 and A_2 are the areas within closed contours 1 and 2, respectively, and E_1 and E_2 are the elevations of contours 1 and 2, respectively.

Cumulative volume above the bottom of the pond, or above the normal water surface elevation, can be calculated by adding subsequent incremental volumes. This is readily accomplished with the use of a spreadsheet prepared as follows (the first row of the table below contains the spreadsheet column header,

$$V_{1-2} = \frac{A_1 + A_2}{2} \times (E_2 - E_1)$$

the second row is column description, and the third, fourth, and fifth rows provide an example, with a permanent pool elevation of 902):

Table 8.40 Example Volume Calculation

Spreadsheet Column Header	Elevation	Area	Average Area	Depth	Volume	Cumulative Volume	Volume Above Permanent Pool
Spreadsheet Column Description	Elevation of Pond Contour Line	Area enclosed by Contour Line	Average area of current and previous rows	Elevation difference between current and previous rows	Volume between current and previous contour	Volume between current and lowest contour	Volume between current and permanent pool contour
Example value	900	1000	N/A	N/A	N/A	0	N/A
Example value	902	1200	1100	2	2200	2200	0
Example value	904	1600	1400	2	2800	5000	2800

The stage-storage relationship will be used to develop a stage-storage-discharge table as outlet structures are designed. This is an iterative process that may include revising the preliminary grading plan and subsequently redetermining the stage-storage relationship (or using an acceptable model to check).

Step 8. Size and design outlet structures.

The following outlet stages should be included in the pond design. It is possible to design one device to meet all stages. Equations included in this step are based on certain assumptions about which types of outlet structures will be used to control the various stages. If the designer chooses to use different structure types, the specific equations used to determine stage-discharge relationships will change, but the general approach will remain the same.

- Emergency drain: a drawdown pipe sized to drain the pond within 24 hours to allow access for riser repairs and sediment removal, or to lower the permanent pool in late fall (to provide additional storage during frozen conditions).
- Water quality (low flow) outlet: an outlet (typically an orifice) designed to release VCS with an average detention time of 12 hours. After designing the orifice, a check should be made to verify that the release rate is no greater than 5.66 cfs/acre of pond surface area. (Calculation steps adapted from Vermont Stormwater Management Manual.)

The average release rate for VCS is computed as:

$$Q_{VCS_avg} = \frac{VCS}{t_{VCS}}$$

Where t_{VCS} is the intended VCS detention time. From the stage-storage table, find the elevation associated with VCS. Calculate the approximate average head on the volume control outlet as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2}$$

Where E_{vcs} is the VCS pool elevation and $E_{PermPool}$ is the elevation of the permanent pool (the invert of the VCS orifice).

The required orifice cross sectional area can then be indirectly computed using the orifice equation:

$$Q_{VCS} = CA_{VCS}\sqrt{2gh_{VCS}}$$

Where C is the orifice coefficient (0.6 is typically used, but may not apply in all cases), A_{VCS} is the orifice area, and g is gravitational acceleration.

The diameter of the orifice is then

$$d_{WQ} = 2 \cdot \sqrt{\left(\frac{A_{VCS}}{\pi}\right)}$$

The rate of discharge from the orifice for any head value h_{VCS} on the orifice can then be computed as:

$$Q_{VCS_avg} = CA_{VCS}\sqrt{2gh_{VCS_avg}}$$

- Rate Control Standard (RCS) outlet: an outlet designed to release the 10-year rainfall over a period of 24 hours (minimum RCS detention time is 12 hours). The RCS pool elevation can be read from the pond stage-storage relationship.

Assuming an orifice is also used to release RCS the invert of the RCS orifice may be placed at the VCS pool elevation (E_{VCS}).

The average release rate for RCS is computed as:

$$Q_{RCS_avg} = \frac{RCS_V - VCS_V}{t_{RCS}} - Q_{VCS}$$

Where t_{RCS} is the intended RCS detention time, and Q_{VCS} is computed (using the above equation for Q_{VCS}), with the head value

$$h_{VCS} = \frac{E_{VCS} + E_{RCS}}{2} - E_{PermPool}$$

From the stage-storage table, find the elevation associated with RCS. The average head on the RCS outlet can then be calculated as:

$$h_{RCS_avg} = \frac{E_{RCS} - E_{VCS}}{2}$$

Again, the required orifice cross sectional area can then be indirectly computed using the orifice equation:

$$Q_{RCS} = CA_{RCS}\sqrt{2gh_{RCS}}$$

The diameter of the orifice is then

$$d_{RCS} = 2 \cdot \sqrt{\left(\frac{A_{RCS}}{\mathrm{p}}\right)}$$

The rate of discharge from the RCS orifice for any head value h_{RCS} on the RCS outlet can then be computed as:

$$Q_{RCS_avg} = CA_{RCS}\sqrt{2gh_{RCS_avg}}$$

The combined flow out of the volume control and rate control orifice at a given water surface elevation can be computed by adding together the discharges from the two structures, for the head values corresponding to the specified water surface elevation.

- Overbank flood control outlet: an outlet (typically a weir) with its invert at the RCS pool elevation, designed to release Qp10 at predevelopment rates (recommended).
- Extreme storm control outlet: an outlet with its invert at or slightly above the Overbank flood control pool elevation, designed to release Qp100 at predevelopment rates (recommended), or at minimum to safely pass the Qp100 with 1' of freeboard between the top of the embankment. Check with the city to determine whether a principal spillway can be used to manage extreme storm flows, or if an emergency spillway (broad-crested weir or earthen embankment, not susceptible to obstruction) is necessary.

Using the determined size information, incorporate the outlet structures into the pond design. Be aware of concerns associated with frozen conditions, particularly the risk of clogging or blockage of outlet structures with ice and the importance of burying pipes below the frost line. A skimmer or similar device is REQUIRED to prevent the discharge of floating debris.

Step 9. Design spillway and embankments.

The following items are some of the key guidelines to adhere to in the design of spillways and embankments.

- It is REQUIRED that the emergency overflow be stabilized.
- It is REQUIRED that embankments be overfilled by at least 5% to account for settling.

- The REQUIRED minimum embankment width is 6' (wider for embankment height >10' or if maintenance access will be required).
- It is REQUIRED that embankments be adequately stabilized with vegetation or other measures.
- It is HIGHLY RECOMMENDED that side slopes be no steeper than 3:1 (h:v).

Additional design guidance and requirements for spillways and embankments are found in NRCS Pond 378 Conservation Practice Standard for Minnesota, which is available at http://efotg.nrcs.usda.gov/references/public/MN/378mn.pdf.

Step 10. Design inlets.

To prevent freezing and blockage of inflow, it is HIGHLY RECOMMENDED that inlet pipes not be fully submerged and that they be buried below the frost line. Frost and thaw depths for several Minnesota sites are shown at the following website: http://www.mrr.dot.state.mn.us/research/seasonal_load_limits/thawindex/frost_thaw_graphs.asp.

It is also HIGHLY RECOMMENDED to design the inlet to reduce or prevent scour, by including riprap or flow diffusion devices such as plunge pools or berms.

Step 11. Design sediment forebay

The size of the sediment forebay was determined in Step 5. It is RECOMMENDED that a sediment marker be included in the forebay to indicate the need for sediment removal in the future. A hard bottom surface in the forebay is also RECOMMENDED in order to make sediment removal easier.

As discussed in Step 6, a weir structure added to the forebay will ensure that some pretreatment storage is available, even when the normal forebay is frozen.

Step 12. Check expected pond performance against regulatory requirements.

Check that V_{wq} is detained for an average of 12 hours.

Check that the V_{wq} release rate does not exceed 5.66 cfs/acre of pond area.

Determine applicable requirements for V_{cp} volume and release rate, and verify that the pond performs adequately for the appropriate design event.

Determine applicable requirements for Q_{p10} and Q_{p100} release rates (e.g., pre-development rates), and check pond release rates (and freeboard) for the appropriate design events.

Step 13. Design maintenance access and safety features.

Maintenance access to the pond, forebay, and inlet and outlet structures is REQUIRED. The access routes should be designed with a minimum 10' width and maximum 15% slope.

Safety features such as obstructive planting that make access difficult, signs warning against fishing and swimming, fencing, and grates over outlet structures should be included as appropriate.

Aesthetic enhancements such as trails or benches can also be included

If an outlet structure is greater than five feet deep, it is REQUIRED that OSHA health and safety guidelines be followed for safe construction and access practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for excavation sites:

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10930

OSHA has prepared a flow chart which will help site owners and operators determine if the site safety plan must address confined space procedures:

Permit-required Confined Space Decision Flow Chart - 1910.146 App A

Step 14. Prepare vegetation and landscaping plan.

A landscaping and planting plan by a qualified professional for the pond and surrounding area should be prepared, utilizing native vegetation wherever possible.

Step 15. Prepare operation and maintenance plan.

Preparation of a plan for operation and maintenance of the pond and associated structures and landscaping is REQUIRED. The key issues related to pond O&M

Step 16. Prepare cost estimate.
Refer to the *Cost Considerations* section for information on preparing a cost estimate for stormwater ponds.

F. Links to Other Manuals

The following links connect to information about wet extended detention ponds contained in other stormwater manuals.

Georgia Stormwater Management Manual
http://www.georgiastormwater.com/vol2/3-2-1.pdf

Idaho Department of Environmental Quality
http://www.deq.state.id.us/water/stormwater_catalog/doc_bmp47.asp

Maryland Department of the Environment
http://www.mde.state.md.us/assets/document/chapter3.pdf

Metropolitan Council
http://www.metrocouncil.org/environment/Watershed/BMP/CH3_STRetenExtended.pdf

Minnesota Pollution Control Agency
http://www.pca.state.mn.us/water/pubs/swm-ch5.pdf

New Jersey Department of Environmental Protection
http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.4%20print.pdf

New York State Dept. of Environmental Conservation
http://www.dec.state.ny.us/website/dow/swmanual/chapter6.pdf

U.S. Dept of Transportation Federal Highway Administration
http://www.fhwa.dot.gov/environment/ultraurb/3fs4.htm

Vermont Water Quality Division
http://www.anr.state.vt.us/dec/waterq/stormwater/docs/sw_manual-vol1.pdf

Western Washington
http://www.ecy.wa.gov/pubs/9915.pdf

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STORMWATER WETLANDS



Stillwater, MN

Definition:
Constructed wetlands systems are used to store and treat runoff by mimicking the function of natural wetlands. However, stormwater wetlands are not natural wetlands and should not be included in natural wetland areas.

KEY CONSIDERATIONS

Design Criteria:

- A water budget should be calculated to ensure proper drainage area and to ensure that wetland conditions can be maintained.
- A minimum length to width ratio of 2:1 should be maintained during low flow or baseflow conditions.
- A minimum of 35% of the total wetland surface area should have a depth of 6 inches or less; 10% to 20% of surface area should be deep pool (1.5 to 6 foot depth).
- Constructed wetlands require about 2% to 4% of the area that drains to them.
- Thermal effects of discharged waters from stormwater wetlands on receiving bodies of water should be considered.

Benefits:

- Good suspended solid and annual nutrient removal
- Provides good wildlife habitat and aesthetic value
- Low maintenance costs
- Provides ground water: surface-water interface

Limitations:

- Requires more land than other practices
- Requires careful design and planning to ensure wetland hydrology is maintained
- Water quality behavior can change seasonally

MANAGEMENT SUITABILITY

	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
X	Settling
X	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

75%	Total Suspended Solids
40%	Nutrients - Total Phosphorus/ Total Nitrogen
40%	Metals - Cadmium, Copper, Lead, and Zinc
75%	Pathogens - Bacteria
85%	Toxins - Hydrocarbon

SITE FACTORS

10-25 AC Min	Drainage Area *small applications may require only 5 acres of drainage area
25%	Max. Slope
3' Min*	Min. Depth to Bedrock *if above water supply aquifer or treating hotspots
3' Min*	Min. Depth to Seasonally High Water Table *if above water supply aquifer or treating hotspots
A,B,C,D	NRCS Soil Type
Good	Freeze/ Thaw Suitability
Yes	Potential Hotspot Runoff *requires impermeable liner

Description:
Stormwater wetlands are constructed shallow marsh systems designed to treat stormwater and, to a lesser extent, control runoff volumes in urban environments. Stormwater wetlands are different from natural systems in that they are specifically designed and constructed for the purpose of managing stormwater runoff. Like natural wetlands, stormwater wetlands require adequate hydrologic input to properly function. Water treatment is achieved through settling of particulates in the wetland system and uptake of nutrients and other constituents in the water by vegetation, soil, and biota. Stormwater wetlands can be very effective at removing pollutants and offer additional benefits in terms of aesthetics, ground water interaction, and wildlife and vegetative habitat.

Stormwater wetlands are best suited to removing contaminants other than sediment from flow. If sediment loads are high, pre-treatment is required. Pre-treatment options include the use of sediment forebays, filter strips, and construction of a pond upstream of the wetland to remove sediment. The choice of a particular pre-treatment option depends on site and hydrologic conditions.

Stormwater wetlands are often termed constructed, artificial, man-made, and engineered wetlands.

Design Variations and Schematics:
There are three (3) basic types of stormwater wetlands: 1) shallow wetland, 2) extended detention (ED) shallow wetland, and 3) pond/wetland systems. Each basic design prescribes different amounts of shallow and deep water and amount of dry storage above the wetland. Following is a brief description of the three major types of stormwater wetlands:

Shallow Wetland – A shallow wetland is designed with different areas of shallow and relatively deeper marsh. The deeper portions of the marsh are located at the sediment forebay at the wetland inlet and the micropool at the wetland's outlet. Shallow wetlands can be designed for smaller drainage areas (5 – 10 acres) though excavation to the water table may be required to sustain wetland hydrology.

Extended Detention (ED) Shallow Wetland – The ED shallow wetland design incorporates additional water quality treatment detention above the surface of the shallow wetland design. The additional storage area is typically designed to dewater in a period of 24 hours so that vegetation is not damaged. This design requires a smaller project footprint than the shallow wetland system because temporary vertical storage is substituted for shallow marsh storage, though water quality treatment may be reduced as residence time and contact time with vegetation is also likely to diminish.

Pond/Wetland Systems – This design incorporates a shallow marsh and wet pond to achieve water quality and quantity goals. Stormwater flows into the wet pond first, where sediments and sediment-bound pollutants have the opportunity to settle out and water velocities are reduced before entering the shallow marsh area. Less land is generally required for the pond/wetland system than for either the shallow wetland or ED shallow wetland designs.

A. Suitability

General

Stormwater wetlands are similar in design to stormwater ponds and mainly differ by their variety of water depths and associated vegetative complex. They require slightly more surface area than stormwater ponds for the same contributing drainage area. Stormwater wetlands are constructed stormwater management practices, not natural wetlands. Like ponds, they can contain a permanent pool and temporary storage for water quality control and runoff quantity control.

Wetlands are widely applicable stormwater treatment practices that provide both water quality treatment and water quantity control. Stormwater wetlands are best suited for drainage areas of at least 10 acres. When designed and maintained properly, stormwater wetlands can be an important aesthetic feature of a site.

Function Within Stormwater Treatment Train

Stormwater wetlands are typically installed at the downstream end of the treatment train (they are considered an end-of-pipe BMP). Stormwater wetland size and outflow regulation requirements can be significantly reduced with the use of additional upstream BMPs. However, when a stormwater wetland is constructed, it is likely to be the only management practice employed at a site, and therefore must be designed to provide adequate water quality and water quantity treatment for all regulated storms.

Inver Grove Heights Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the city of Inver Grove Heights' Volume Control Standard. This standard must be met on all new and re-development projects taking place in the northwest area.

Stormwater wetlands generally may be used to meet the Inver Grove Heights pretreatment requirements. (Chapter 6) Stormwater wetland systems that incorporate infiltration may also reduce the 5-year 24-hour infiltration standard by the amount that the practice is able to store and infiltrate.

The following terms are thus used in the text to distinguish various levels of green roof design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Stormwater wetlands are constructed with varying amounts of the following three components:

- Shallow marsh area
- Permanent micropool area
- Storage volume above the normal water level

The amount of each of the components named above depends on the desired type of stormwater wetland (e.g., shallow wetland).

Stormwater wetland design must be tailored to site characteristics; however, some general RECOMMENDED design criteria for shallow wetland, ED shallow wetland, and pond/wetland design are presented in Table 8.41.

Table 8.41 Stormwater wetland general design criteria

Design Criteria	Shallow Wetland	Pond/Wetland	ED Shallow Wetland[1]
Wetland/Watershed Ratio	0.2	0.1	0.1
Minimum Drainage Area	25	10	25
Length to Width Ratio (minimum)	2:1	2:1	2:1
Extended Detention (ED)	No	Optional	Yes
Allocation of Permanent Pool Volume (pool/marsh/ ED) in %	25/75/0	70/30/0 (includes pond volume)	25/25/50
Allocation of Surface Area (deepwater/low marsh/ high marsh/semi-wet) in %	20/35/40/5	45/25/25/5 (includes pond surface area)	10/35/45/10
Forebay	Required	Required	Required
Micropool	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir

Note: The ED Shallow Wetland design guidance does not meet the MPCA requirements for permanent volume. The guidance may be applied in a stormwater retrofit situation where area requirements preclude the use of a Shallow Wetland.

The proportion of deep water, low marsh, high marsh, and semi-wet marsh is presented above in Table 8.41 and are defined as:

- ***Deepwater zone*** – From 1.5 to 6 feet deep. Includes the outlet micropool and the deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation but may support submerged or floating vegetation.
- ***Low marsh zone*** – From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growing of several emergent wetland plant species.
- ***High marsh zone*** – From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.
- ***Semi-wet zone*** – Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

Retrofit Suitability

As a retrofit, stormwater wetlands have the advantage of providing both educational and habitat value. One disadvantage of wetlands, however, is the difficulty in storing large amounts of runoff without consuming a large amount of land. Therefore, the most common type of wetland retrofit involves the modification of an existing dry or wet pond.

Cold Climate Suitability

Wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Because stormwater wetlands are relatively shallow, freezing of the shallow pool can occur. Also, freezing of inlet and outlet structures can occur, which will reduce performance of the stormwater wetland. To avoid these problems, the CWP (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes “turn the corner” are helpful.
- Increase the slope of inlet pipes to a minimum of 1% to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½”. In addition, the pipe should have a minimum 6” diameter.
- When a standard weir is used, the minimum slot width should be 3", especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6" below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water quality events. This practice was both avoids stream warming and is also a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation.

Water Quantity Treatment

Stormwater wetlands are well-suited to meet the rate control standard (RCS) and act as pretreatment for the volume control standard (VCS). As in ponds, this is accomplished with live storage (extended detention) above the permanent pool. It is HIGHLY RECOMMENDED that when providing water quantity control in stormwater wetlands, the smallest possible bounce (vertical water level fluctuation) be sought, in order to limit the amount of stress on the vegetation.

Water Quality Treatment

Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and biota (algae, bacterial), vegetative filtering, soil adsorption, and gravitational settling in the slow moving marsh flow. Volatilization and chemical activity can also occur, breaking down and assimilating a number of other stormwater contaminants such as hydrocarbons.

Pollutant removal efficiencies and optimum effluent concentrations for select parameters are provided in Tables 8.42 and 8.43, respectively.

Table 8.42 Percent Removal of Key Pollutants

Practice	TSS [%]	Total Phosphorus [%]	Total Nitrogen [%]	Metals[1] [%]	Bacteria [%]	Hydro-carbons [%]
Stormwater Wetlands	76	49	30	42	78[2]	85[2]

1. Average of zinc and copper.
2. Based on fewer than five data points (i.e., independent monitoring studies)

Removals represent median values from Winer (2000)

Table 8.43 Typical BMP Best Attainable Effluent Concentrations					
Practice	TSS [mg/l]	TP [mg/l]	TN [mg/l]	Cu [ug/l]	Zn [ug/l]
Wetlands	6	0.2	1.7	3.0	50
Values from ASCE bmp database and Winer 2000					

Limitations

The following general limitations should be recognized when considering installation of stormwater wetlands:

- they require more land than other practices
- they require careful design and planning to ensure wetland hydrology is maintained
- water quality behavior can change seasonally

B. Major Design Elements

Physical Feasibility Initial Check

Before deciding to construct a wetland for stormwater management, it is helpful to consider several items that bear on the feasibility of using a wetland at a given location. The following list of considerations will help in making an initial judgment as to whether or not a wetland is the appropriate BMP for the site.

- ***Drainage Area*** – 25 acres minimum HIGHLY RECOMMENDED, ensuring hydrologic input sufficient to maintain permanent pool; 10 acres (or less) may be acceptable, particularly if the groundwater table is intercepted and a water balance indicates that a permanent pool can be sustained.
- ***Space Required*** – Approximately 2-4% of the tributary drainage area is RECOMMENDED for wetland footprint.
- ***Minimum Head*** – The elevation difference RECOMMENDED at a site from the inflow to the outflow is 6-10 feet.
- ***Minimum Depth to Water Table*** – In general, there is no minimum separation distance required with stormwater wetlands. In fact, intercepting the groundwater table is common and helps sustain a permanent pool. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer, which means that a liner might be required for portions of the wetland with standing water.
- ***Soils*** – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. Most group “A” soils and some group “B” soils will require a liner. A site specific geotechnical investigation should be performed. Also, if earthen embankments are to be constructed, it will be necessary to use suitable soils.
- ***Groundwater Protection*** –It is REQUIRED that stormwater wetlands treating runoff from PSHs provide excellent treatment capabilities. In some cases (depending on the land use and associated activities), lining the stormwater wetland may be necessary to protect groundwater, particularly when the seasonally high groundwater elevation is within three feet of the practice bottom.

Conveyance

Inflow Points

- ► It is HIGHLY RECOMMENDED that inlet areas be stabilized to ensure that non-erosive conditions exist during events up to the design event. It is HIGHLY RECOMMENDED that inlet pipe inverts be located at the permanent pool elevation. Submerging the inlet pipe is can result in freezing and upstream damage.
- ► It is HIGHLY RECOMMENDED that inlet pipes have a slope of no flatter than 1%, to prevent standing water in the pipe and reduce the potential for ice formation.
- ► It is HIGHLY RECOMMENDED that pipes be buried below the frost line, to prevent frost heave and pipe freezing.
- ► It is HIGHLY RECOMMENDED that where open channels are used to convey runoff to the wetland, the channels be stabilized to reduce the sediment loads.

Adequate Outfall Protection

Stormwater wetland outfalls should be designed to not increase erosion or have undue influence on the downstream geomorphology of the stream.

- ► It is HIGHLY RECOMMENDED that a stilling basin or outlet protection be used to reduce flow velocities from the principal spillway to non-erosive velocities (3.5 to 5.0 fps).
- ► Flared pipe sections that discharge at or near the stream invert or into a step-pool arrangement are RECOMMENDED over headwalls at the spillway outlet.
- ► It is RECOMMENDED that tree clearing be minimized along the downstream channel and that a forested riparian zone be reestablished in the shortest possible distance. It is also RECOMMENDED that excessive use of riprap be avoided, to minimize stream warming in channels with dry weather flow.
- ► Local agencies (Watershed Districts, Watershed Management Organizations (WMOs), municipalities, etc.) may have additional outlet control requirements.

Pretreatment

Sediment forebays are the RECOMMENDED pretreatment method for stormwater wetlands, although other features, such as grassed swales, could be used to remove sediment from runoff before it enters the wetland system. A forebay or equivalent pretreatment should be in place at each inlet to ease the maintenance burden and preserve the longevity of the stormwater wetland. See the section on Stormwater Ponds for design guidance.

Treatment

Permanent Pool and Volume Control Standard (VCS)

Stormwater wetlands follow similar sizing criteria as stormwater ponds. See the Stormwater Ponds section for guidance on sizing the permanent pool volumes, volume control standard volume, and depth.

A water balance is recommended to document sufficient inflows to maintain a constant wetland pool and sustain wetland vegetation during prolonged dry weather conditions. This is of particular importance in stormwater wetlands. The basic approach to performing a water balance is as follows:

1. Check maximum drawdown during periods of high evaporation and during an extended period of no appreciable rainfall to ensure that wetland vegetation will survive.
2. The change in storage within a wetland = inflows – outflows.
3. Potential inflows: runoff, baseflow and rainfall.
4. Potential outflows: infiltration, surface overflow and evapotranspiration
5. Assume no inflow from baseflow, no outflow losses for infiltration and because only the permanent pool volume is being evaluated, no outflow losses for surface overflows. The validity of these assumptions need to be verified for each design.
6. Therefore, storage = runoff - evaporation

If a liner is required for the stormwater wetland, it should be designed following the same guidance as for stormwater ponds.

Grading and Site Layout

Site layout and grading affect the pollutant removal capability of the stormwater wetlands as well as the ease of maintenance. Performance is enhanced when multiple cells, longer flowpaths, high surface area to volume ratios, and complex microtopography are used. Specific design considerations for site layout include:

- It is RECOMMENDED that the minimum length to width ratio for ponds be 2:1.
- It is RECOMMENDED that to the greatest extent possible, stormwater wetlands be irregularly shaped and long flow paths be maintained.
- Microtopography (small irregular 6 to 24 inch variations in bottom topography) is RECOMMENDED to enhance wetland diversity.
- It is HIGHLY RECOMMENDED that at least 25% of the wetland pool volume of a stormwater wetland be in deepwater zones with a depth greater than four feet.
- It is HIGHLY RECOMMENDED that a minimum of 35% of the total surface area of stormwater wetlands should have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches.
- It is HIGHLY RECOMMENDED that a micropool be excavated at the pond outlet to prevent resuspension of sediments.
- It is HIGHLY RECOMMENDED that the extended detention associated with the VCS and RCS not extend more than three feet above the permanent pool at its maximum water surface elevation.
- It is HIGHLY RECOMMENDED that berms be used to separate wetland cells. This reduces the incidence of freezing and requires less maintenance than pipes or concrete weirs.
- Structures such as fascines, coconut rolls, straw bales, or carefully designed stone weirs can be used to create shallow marsh cells in high-energy areas of the stormwater wetland.
- It is HIGHLY RECOMMENDED that the perimeter of all deep pool areas (four feet or greater in depth) be surrounded by a safety bench and aquatic bench, as described in the stormwater ponds section. The aquatic benches can be incorporated into the pond microtopography.

Landscaping

Landscaping Plan

There are many references describing suitable native species of plants for Minnesota. The reader is referred to the Appendix B as well as to Shaw, D. and R. Schmidt. 2003. Plants for Stormwater Design. Minnesota Pollution Control Agency, St. Paul, MN. The following guidelines are RECOMMENDED for landscaping of stormwater wetland facilities.

- A landscaping plan shall be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of pondscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
- Vegetation selection should be based on the anticipated hydrologic function of the stormwater wetland (e.g. water level fluctuation).
- Design should consider control – predation by carp, geese, deer, etc.
- Donor soils for stormwater wetland mulch should not be removed from natural wetlands.
- Wetland soils mix often contain wetland plant propagules that help to establish the plant community.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the stormwater wetland and buffers.
- The planting schedule should reflect the short growing season. Designers should consider incorporating relatively mature plants, or planting dormant rhizomes during the winter.

- If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting is required.
- It is RECOMMENDED that a landscape architect or another landscape professional be consulted in selection of wetland plants.

Safety

- It is REQUIRED that public safety be considered in every aspect of stormwater wetland design.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.
- The access and aquatic benches should be landscaped to prevent access to the wetland.
- Warning signs prohibiting swimming, skating, and fishing should be posted.
- Wetland fencing is generally not encouraged, but may be required by some municipalities. A preferred method is to grade the pond to eliminate steep drop-offs or other safety hazards.
- Dam safety regulations should be strictly followed with stormwater wetland design to ensure that downstream property and structures are adequately protected.

C. Construction Details and Specifications

CADD based details for pond systems are contained in Appendix A. The following details, with specifications, have been created for stormwater ponds/wetlands:

- Extended Detention Shallow Wetland Plan
- Extended Detention Shallow Wetland Profile
- Outlet Structures

D. Operation and Maintenance

Overview

Maintenance is necessary for a stormwater wetland to operate as designed on a long-term basis. The pollutant removal capabilities of stormwater wetlands will decrease if:

- Wetland pool elevations fluctuate dramatically
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants out-compete the wetland plants
- Sediment accumulates in the stormwater wetland, reducing the storage volume
- Slope stabilizing and desirable wetland vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised.

Stormwater wetland maintenance activities range in terms of the level of effort and expertise required to perform them. Routine stormwater wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year, but can be performed by citizen volunteers. More significant maintenance, such as removing accumulated sediment, is needed less frequently but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) that has experience in the construction, inspection, and repair of these features.

Design Phase Maintenance Considerations

Implicit in the design guidance in the previous sections, many design elements of stormwater wetland systems can minimize the maintenance burden and maintain pollutant removal efficiency. Primarily, providing easy access (typically 8 feet wide) to stormwater wetlands for routine maintenance is REQUIRED.

Mosquito control is of particular concern in the case of stormwater wetlands. They can be properly designed, constructed and maintained to minimize the likelihood of being desirable habitat for mosquito populations. Designs that incorporate constant inflows and outflows, habitat for natural predators, and constant permanent pool elevations limit the conditions typical of mosquito breeding habitat. See Chapter 6 for an in-depth discussion of mosquito concerns in stormwater management.

Construction Phase Maintenance

The construction phase is another critical step where O&M issues can be minimized or avoided. Inspections during construction are needed to ensure that the stormwater wetland is built in accordance with the approved design and standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor's interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided in Appendix D.

Post Construction Operation and Maintenance

Some important post construction maintenance considerations are provided below. A more detailed checklist of maintenance activities and associated schedules is provided in Appendix D. More detailed maintenance guidance can be found in the Pond and Wetland Maintenance Guidebook (CWP, 2004).

- It is REQUIRED that a legally binding and enforceable maintenance agreement be executed between the practice owner and the city of Inver Grove Heights.
- Adequate access must be provided for inspection, maintenance, and landscaping upkeep, including appropriate equipment and vehicles. It is RECOMMENDED that a maintenance right of way or easement extend to ponds from a public or private road.
- It is HIGHLY RECOMMENDED that stormwater wetlands be inspected annually during winter freeze periods to look for signs of improper operation.
- It is HIGHLY RECOMMENDED that sediment removal in the forebay occur every 2 to 7 years or after 50% of total forebay capacity has been lost. In areas where road sand is used, an inspection of the forebay and stormwater wetland should be scheduled after the spring melt to determine if clean-out is necessary.
- Sediments excavated from stormwater wetlands that do not receive runoff from confirmed hotspots are generally not considered toxic or hazardous material, and can be safely disposed by either land application or land filling. Sediment testing may be necessary prior to sediment disposal when a confirmed hotspot land use is present.
- Periodic mowing of the stormwater wetland buffer is HIGHLY RECOMMENDED along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year), prairie, or forest.
- General maintenance activities and schedule are provided in Table 8.44.

Table 8.44 Typical Inspection/Maintenance Frequencies for Stormwater Wetlands		
Inspection Items	**Maintenance Items**	**Frequency**
► Ensure that at least 50% of wetland plants survive ► Check for invasive wetland plants	► Replant wetland vegetation	One time - After First Year
► Inspect low flow orifices and other pipes for clogging ► Check the permanent pool or dry pond area for floating debris or undesirable vegetation ► Investigate the shoreline for erosion ► Monitor wetland plant composition and health ► Look for broken signs, locks, and other dangerous items	► Mowing – minimum Spring and Fall ► Remove debris ► Repair undercut, eroded, and bare soil areas	Monthly to Quarterly or After Major Storms (>1”)
► Monitor wetland plant composition and health ► Identify invasive plants ► Assure mechanical components are functional	► Trash and debris clean-up day ► Remove invasive plants ► Harvest wetland plants ► Replant wetland vegetation ► Repair broken mechanical components if needed	Semi-annual to annual
► All routine inspection items above ► Inspect riser, barrel, and embankment for damage ► Inspect all pipes ► Monitor sediment deposition in facility and forebay	► Pipe and Riser Repair ► Forebay maintenance and sediment removal when needed	Every 1 to 3 years
► Monitor sediment deposition in facility and forebay	► Forebay maintenance and sediment removal when needed	2-7 years or 50% loss of sediment forebay storage
► Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping	► Sediment removal from main pond/wetland ► Pipe replacement if needed	5-25 years

Cost Considerations

Cost factors for stormwater management ponds are extremely sensitive to site conditions. Availability of in situ materials for embankment construction, outlet protection, cost of excavation, liner materials, and land costs are significant factors. Maintenance and inspection costs for mowing and periodic dredging are post-development factors. Other technologies such as infiltration trenches may be more cost-effective in smaller drainage areas due to construction and long-term maintenance costs (Young et al., 1996). Costs for ponds typically include costs for embankment, riser and spillway structures, outfall protection, vegetative stabilization, excavation, and grading. Additional costs for site preparation can include soil amendments, precision grading, plant materials and creation of occluding layers in coarse-textured soil types if wetlands systems must be created on upland sites due to project constraints. Project costs can be lowered if existing pre-construction site conditions are carefully considered and isolated areas with hydric soils contained within the footprint of the project are utilized as stormwater management facilities.

Additional maintenance costs will be incurred until the establishment of the wetland ecosystem. Invasive plants must be culled and dead plants replaced. The outlet structure may have to be adjusted, based on seasonal observations, to achieve the proper water surface in the pond. (FHWA Ultra Urban BMP Manual).

Detailed Cost Estimate

The most appropriate technique for determining the cost to construct and maintain a specific BMP will be to apply unit costs to each component of construction, operation and/or maintenance. Table 8.45 represents the typical components for stormwater wetlands. This table presents those components of a construction project that are unique to this Best Management Practice. Costs that would be associated with all aspects of a construction site, such as erosion and sediment control, mobilization, or traffic control, are not presented as unique costs.

Designers are encouraged to use the cost worksheet included in Appendix F to estimate their BMP construction cost.

Table 8.45 Typical components of stormwater wetlands

Implementation Stage	Primary Cost Components	Basic Cost Estimate	Other Considerations
Site Preparation	Tree & plant protection	Protection Cost ($/acre) x Affected Area (acre)	Removal of existing structures, topsoil removal and stockpiling
	Topsoil salvage	Salvage Cost ($/acre) x Affected Area (acre)	
	Clearing & grubbing	Clearing Cost ($/acre) x Affected Area (acre)	
Site Formation	Excavation / grading	4-ft Depth Excavation Cost ($/acre) x Area (acre)	Soil & rock fill material, tunneling
	Hauling material offsite	Excavation Cost x (% of Material to be hauled away)	
Structural Components	Inlet structure	($/structure)	Pipes, catchbasins, manholes, valves
	Outlet structure	($/structure)	

Table 8.45 Typical components of stormwater wetlands			
Implementation Stage	**Primary Cost Components**	**Basic Cost Estimate**	**Other Considerations**
Site Restoration	Soil Preparation	Soil cost ($/acre) x Seeding/ planting area (1 ft average depth per acre)	Tree protection, soil amendments, seed bed preparation, trails
	Seeding (or sodding)	Seeding Cost ($/acre) x Seeded Area (acre)	
	Planting / transplanting	Planting Cost ($/acre) x Planted Area (acre)	
Annual Operation, Maintenance, and Inspection	Debris removal	Removal Cost ($/acre) x Area (acre) x Frequency (2 / 1yr)	Vegetation maintenance, cleaning of structures
	Invasive plant removal	Labor Cost ($/hr) x Time x Frequency	
	Sediment removal	Removal Cost ($/acre) x Area (acre) x Frequency (1 / 5yr)	
	Erosion Repair	Repair cost ($/area) x Area Affected	
	Gate / valve operation	Operation Cost ($) x Operation Frequency (2 / 1 yr)	
	Inspection	Inspection Cost ($) x Inspection Frequency (2 / 1 yr)	
	Mowing	Mowing Cost ($) x Mowing Frequency (4 / 1 yr)	

E. Design Procedure

The following steps outline a recommended design procedure for a wet extended detention pond (wet sedimentation basin) in compliance with the Inver Grove Heights Stormwater Permit. Design recommendations beyond those specifically required by the permit are also included and marked accordingly.

Step by Step Design Procedure:

Step 1. Make a preliminary judgment as to whether site conditions are appropriate for the use of a stormwater wetland, and identify the function of the wetland in the overall treatment system

A. Consider basic issues for initial suitability screening
- ► Site drainage area
- ► Soils
- ► Slopes
- ► Space required for wetland

- ► Depth to water table
- ► Minimum head
- ► Receiving waters

B. Determine how the wetland will fit into the overall stormwater treatment system
   - ► Are other BMPs to be used in concert with the constructed wetland?
   - ► Will a pond be part of the wetland design and if so, where?

Step 2. Confirm local design criteria and applicability

A. Determine whether the wetland must comply with the MPCA Permit.
B. Check with Inver Grove Heights officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Confirm site suitability

A. Perform field verification of site suitability.
   - ► If the initial evaluation indicates that a pond would be a good BMP for the site, it is RECOMMENDED that a sufficient number of soil borings should be taken to ensure wetland conditions (hydrologic and vegetative) can be maintained after construction. The number of borings will vary depending on size of the site, parent material and design complexity. For example, a design that requires compacted earth material to form a dike will likely require more borings than one without this feature.
   - ► It is RECOMMENDED that the soil borings or pits be five feet below the bottom elevation of the proposed stormwater wetland.
   - ► It is HIGHLY RECOMMENDED that the field verification be conducted by a qualified geotechnical professional.

B. Perform water balance calculations if needed.

Step 4. Compute runoff control volumes and permanent pool volume.

If the pond is being designed as a wet detention pond for new construction under the MPCA Permit, then a permanent pool volume equal to 1800 cubic feet for each acre draining to the pond is REQUIRED. This can be calculated as:

$$\text{Permanent Pond Volume} = 1800 \left[\frac{ft^3}{Ac}\right] * A\,[Ac]\ [ft3]$$

If part of the overall VCS is to be treated by other BMPs, subtract that portion from the VCS to determine the part of the VCS to be treated by the pond. It is assumed that the pond will be the only BMP used for rate control for larger storms.

Step 5. Determine pretreatment (sediment forebay) volume (HIGHLY RECOMMENDED)

In the absence of adequate upstream treatment by other BMPs, it is HIGHLY RECOMMENDED that a sediment forebay or similarly effective pretreatment system be provided at each inlet providing 10% or more of the total design inflow, with a RECOMMENDED volume equal to 10% of the permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool requirement. Likewise, the storage volumes from other BMPs used upstream in the treatment train count toward the total permanent pool requirement and thus may be subtracted.

Step 6. Allocate the Permanent Pool volume among marsh, micropool, and ED volumes

Taking into consideration that 10% of the required volume has already been allocated to the pretreatment forebay or managed by some other BMP, the remaining 90% of the required volume may be allocated between marsh, micropool, and ED volumes using the recommendations presented in Table 8.41.

Volumes may be calculated as follows:

$$Vol_{pool} = 0.15 * (WP_v [ft^3])$$
$$Vol_{marsh} = 0.75 * (WP_v [ft^3])$$

$$Vol_{pool} = 0.15 * (WP_v [ft^3])$$
$$Vol_{marsh} = 0.25 * (WP_v [ft^3])$$
$$Vol_{ED} = 0.5 * (WP_v [ft^3])$$

Shallow Wetland:
Shallow ED Wetland:

Step 7. Determine wetland location and preliminary geometry, including distribution of wetland depth zones

This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deep water). A stage-storage relationship should be developed to describe the storage requirements and to set the elevation of the wetland pool elevation, the volume control standard volume, the extended detention volume (if applicable), the rate control standard volume, etc.

The proportion of surface area to place in the various depth zones for each type of constructed wetland is shown in Table 8.41. Other guidelines for constructed wetland layout are:

- Provide maintenance access (8' width for trucks/machinery)
- Length to width ratios are presented in Table 8.41

Step 8. Compute extended detention orifice release rate(s), and establish Rate Control Standard (RCS) elevation

Shallow Wetland: The RCS elevation is determined from the stage-storage relationships and the orifice is then sized to release the RCS volume over a 24-hour period. The rate control orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 12 to 18 inches below the elevation of the wetland pool, or 6 inches below the normal ice depth, where outlet depths permit, is recommended. Adjustable gate valves can also be used to achieve these equivalent diameters.

1. The time period over which to release the RCS volume is typically 24 hours.

2. The release rate may then be calculated by:

$$Q_{VCS_avg} = \frac{VCS}{t_{WQ}} \quad [cfs]$$

where t_{VCS} is the time in seconds determined above. Check to determine if Q_{VCS} is less than or equal to 5.66 cfs per acre of surface area of the wetland. If Q_{VCS} meets the criterion, proceed to the next step in

the process. If Q_{VCS} is greater than 5.66 cfs, the release time should be increased or a two-stage outlet should be used whereby the first outlet is able to discharge VCS to meet the permit requirements. A two-stage outlet procedure is presented for the ED Shallow Wetland.

3. The average head is calculated as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2} \text{ [ft]}$$

where E_{vcs} is the VCS pool elevation and $E_{PermPool}$ is the wetland pool elevation.

4. Given the design release rate, estimated in #2 above, an outlet may be sized using either the weir or orifice equations.

5. The discharge from the wetland can then be computed for any elevation between the RCS elevation and the wetland pool elevation.

ED Shallow Wetland: Based on the elevations established in Step 6 for the extended detention portion of the volume control standard volume, the water quality orifice is sized to release this extended detention volume in 24 hours. If a water quality orifice is used, it should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The RCS elevation is then determined from the stage-storage relationship. The invert of the rate control standard orifice is located at the volume control extended detention elevation, and the structure outlet is sized to release the RCS volume over a 24-hour period.

Steps to compute the ED orifice are similar to those presented above for the Shallow Wetland. In this procedure VCS is equal to the extended detention volume.

1. The time period over which to release the VCS volume is typically 24 hours.

2. The release rate may then be calculated by:

$$Q_{VCS_avg} = \frac{VCS}{t_{VCS}} \text{[cfs]}$$

where t_{VCS} is the time in seconds determined above in 2. Check to determine if Q_{VCS} is less than or equal to 5.66 cfs per acre of surface area of the wetland. If Q_{VCS} meets the criterion, proceed to the next step in the process. If Q_{VCS} is greater than 5.66 cfs, the release time should be increased.

3. The average head is calculated as:

$$h_{vcs_avg} = \frac{Evcs - E_{PermPool}}{2} \text{ [ft]}$$

where $Evcs$ is the elevation of the volume control standard water elevation and $E_{PermPool}$ is the wetland pool elevation.

4. Depending upon the outlet configuration, use the weir or orifice equation to calculate the outlet size.

5. The discharge from the wetland can then be computed for any elevation between the RCS elevation and the wetland pool elevation.

6. The release rate may then be calculated by:

$$Q_{RCS} = \frac{RCS\,[ft^3] - VCS\,[ft^3]}{t\,[s]} - Q_{VCS}(@\ RCS_v EL)$$

where t is the time in seconds determined above in 2. Check to determine if Q_{RCS} meets all design requirements.

6. The average head is calculated as:

$$h_{RCS_avg} = \frac{E_{RCS} - E_{VCS}}{2} \quad [ft]$$

where E_{RCS} is the elevation of the Rate Control Standard Volume and E_{VCS} is the Volume Control Standard Elevation

7. The orifice equation can then be used to calculate the orifice opening, A, as:

$$A_{RCS} = \frac{Q_{RCS}[cfs]}{C(2g[ft/s^2]h_{avg}[ft])^{0.5}} \quad [ft^2]$$

where g [ft/s/s] is the gravitational constant equal to 32.2 ft/s^2,
The discharge coefficient, C, can be conservatively estimated to be 0.6.

The diameter of the opening can then be solved for:

$$d_{RCS} = 2\left(\frac{A_{RCS}\,[ft^2]}{\pi}\right)^{0.5} \quad [ft]$$

8. The discharge from the wetland can then be computed for any elevation above the volume control standard elevation as:

$$Q_{RCS} = Kh^{0.5} \quad [cfs]$$

where $K = CA_{RCS}\,[ft](2g[\frac{ft}{s^2}])^{0.5}$ and $h = wse\,[ft] - E_{permpool}\,[ft] - d_{RCS}/2\,[ft]$

Step 9. Design embankment(s) and spillway(s)

For local stormwater management, size the emergency spillway for events larger than the 100-year 24-hour rainfall event. For regional stormwater management facilities, the design criteria for the emergency spillway can be found in the Overflow Contingency Plan.

At final design, provide safe passage for the 100-year event. Attenuation may not be required.

The following guidelines should also be followed (see NRCS Practice Standard 378 for further guidance):

- Embankments should be stabilized with vegetation (no trees) or riprap.
- Embankments may require a core-trench if geotechnical considerations warrant
- Embankment side slopes should not be steeper than 3H:1V on the front, 2H:1V on the back (impounded side).

- Minimum embankment top width is 6' (8' if equipment access is necessary)
- Material consolidation and shrinkage needs to be factored into embankment design
- Emergency overflows must be stabilized

Step 11. Design Inlets

To prevent freezing and associated blockage of the inflow, inlet pipes should not be completely submerged. It is also important to design the inlet to reduce or prevent scour, by including riprap or flow diffusion devices such as plunge pools or berms. To prevent standing water in the pipe, which reduces the potential for ice formation in the pipe, increase the slope to 1% if conditions permit.

Step 12. Design sediment forebay

It is recommended that a sediment marker be included in the forebay to indicate the need for sediment removal in the future. Also, a hard bottom surface in the forebay will make sediment removal easier, but note that a hard bottom surface will likely result in reduced vegetative and biotic processes that remove pollutants.

Step 13. Design outlet structures,

Be aware of concerns associated with frozen conditions, particularly the risk of clogging or blockage of outlet structures with ice.

- For weir structures, the minimum slot width should be 3".
- The minimum outlet pipe diameter should be 18", with a minimum slope of 1%.
- Outlet pipes should be buried below the frost line to the extent possible. Information on frost depths can be found from the Minnesota Department of Transportation at : http://www.mrr.dot.state.mn.us/research/seasonal_load_limits/thawindex/frost_thaw_graphs.asp
- If a riser pipe with an orifice outlet is used, the orifice should be protected by a hood that draws water from 12 to 18 inches below the normal wetland pool elevation, or 6" below the normal ice layer if known, if outlet site conditions permit.
- Trash racks should be installed at a shallow angle in order to discourage ice formation.
- A baffle weir or skimmer can be used to keep organic floatables in the wetland and prevent ice or debris from blocking the outlet.

Also, outlet pipes through the embankment should be equipped with an anti-seepage collar to prevent failure.

Step 14. Design maintenance access and safety features.

- Maintenance access to the pond, forebay, and inlet and outlet structures is REQUIRED. The access routes should be designed with a minimum 8' width and maximum 15% slope.
- Safety features such as obstructive planting that make access difficult, signs warning against fishing and swimming, fencing, and grates over outlet structures should be included as appropriate.
- Aesthetic enhancements such as trails or benches can also be included

Step 15. Prepare Vegetation and Landscaping Plan

See Major Design Elements for guidance on preparing vegetation and landscaping management plan.

Step 15. Prepare Operations and Maintenance (O&M) Plan

See Operations and Maintenance for guidance on preparing an O&M plan.

F. Links to Other Manuals

The following links connect to information about wet extended detention ponds contained in other stormwater manuals. Links to information about other types of ponds is not included here, because of their limited applicability in Minnesota.

Georgia Stormwater Management Manual
http://www.georgiastormwater.com/vol2/3-2-1.pdf

Idaho Department of Environmental Quality
http://www.deq.state.id.us/water/stormwater_catalog/doc_bmp47.asp

Maryland Department of the Environment
http://www.mde.state.md.us/assets/document/chapter3.pdf

Metropolitan Council
http://www.metrocouncil.org/environment/Watershed/BMP/CH3_STRetenExtended.pdf

Minnesota Pollution Control Agency
http://www.pca.state.mn.us/water/pubs/swm-ch5.pdf

New Jersey Department of Environmental Protection
http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.4%20print.pdf

New York State Dept. of Environmental Conservation
http://www.dec.state.ny.us/website/dow/swmanual/chapter6.pdf

U.S. Dept of Transportation Federal Highway Administration
http://www.fhwa.dot.gov/environment/ultraurb/3fs4.htm

Vermont Water Quality Division
http://www.anr.state.vt.us/dec/waterq/stormwater/docs/sw_manual-vol1.pdf

Western Washington
http://www.ecy.wa.gov/pubs/9915.pdf

G. References

ASCE/EPA International Stormwater Best Management Practices (BMP) Database. http://www.bmpdatabase.org/.

Caraco, D. and R. Claytor. 1997. *Stormwater BMP Design Supplement for Cold Climates*. Center for Watershed Protection. Ellicott City, MD.

Center for Watershed Protection, 2004. *Stormwater Pond and Wetland Maintenance Guidebook*.

(FHWA Ultra Urban BMP Manual) "Ultra-Urban Best Management Practices." Federal Highway Administration, Washington, D.C., 1997 http://www.fhwa.dot.gov/environment/ultraurb/index.htm

Minnesota Climatology Working Group

MPCA, 2000. *Protecting Water Quality in Urban Areas*.

Natural Resources Conservation Service. Conservation Practice Standard 378, Pond.

Shaw, D. and R. Schmidt. 2003. Plants for Stormwater Design. Minnesota Pollution Control Agency, St. Paul, MN.

Winer, R. 2000. *National Pollutant Removal Performance Database*. Center for Watershed Protection, Ellicott City, MD.

Young, G Kenneth, Stuart Stein, Pamela Cole, Traci Kammer, Frank Graziano, Fred Bank. 1996. Evaluation and Management of Highway Runoff Water Quality. Office of Environment and Planning, Federal Highway Administration, Washington, D.C.

SOIL AMENDMENTS



Northwest Biosolids Management Association (2006)

Definition:
Soil amendments include a variety of soil impact minimization techniques that maintain or restore the impacts of grading on soil structure. The result of these practices is increased stormwater infiltration and filtration.

KEY CONSIDERATIONS

Design Criteria:

- Soil amendments should be used on graded sites to restore the pre-construction soil structure and encourage infiltration/filtration of stormwater.
- Identify the type of soil amendment to be used. Not disturbing native soils is the most cost-effective option, but is not always feasible.
- Amending soils with compost restores the organic matter of disturbed soils.

Benefits:

- Reduced stormwater runoff and associated infrastructure.
- Increased groundwater recharge
- Healthier vegetation

Limitations:

- Limited monitoring data are available
- Initial cost is higher than not amending soils, although savings from stormwater infrastructure can offset this cost
- Area must be fenced off from construction traffic after soils are amended.

MANAGEMENT SUITABILITY

X	Volume Control
X	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
X	Wetland Bounce

MECHANISMS

X	Infiltration
X	Screening/ Filtration
X	Temperature Control
	Settling
	Evaporation
X	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

NA	Total Suspended Solids
NA	Nutrients - Total Phosphorus/ Total Nitrogen
NA	Metals - Cadmium, Copper, Lead, and Zinc
NA	Pathogens - Bacteria
NA	Toxins - Hydrocarbon

SITE FACTORS

Any	Drainage Area
Any	Max. Slope
0 ft.	Min. Depth to Bedrock
0 ft.	Min. Depth to Seasonally High Water Table
Any	NRCS Soil Type
Good	Freeze/ Thaw Suitability
Yes	Potential Hotspot Runoff

Description:
Soil amendments can be subdivided into five categories (A-E)

A) Undisturbed Native Soil – Protect native soils from compaction during the construction phase.

B) Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

C) Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface. “Manufactured” topsoil mixes should be weed free, making them ideal for seeding new lawns.

D) Native Soil: Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled and reapplied after grading or other construction disturbances are completed. Stockpiling may not be practical on small sites.

E) Disturbed Soil: Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled, reapplied after grading and amended.

A. Suitability

General

Healthy soil is vital to a clean environment and healthy landscapes. Deep soil that is rich in organic material absorbs and infiltrates rainwater, prevents flooding and soil erosion, and filters out pollutants typically associated with stormwater runoff. Healthy soil also stores water and nutrients for plants to use in dry times, promoting healthy plants that require less irrigation and pesticides.

Land development and landscaping practices can damage these valuable soil functions by removing or compacting topsoil. The result is decreased infiltration, increased erosion, unhealthy landscapes that are difficult and expensive to maintain, polluted water, impaired fish habitat, and increased need for stormwater management structures.

Ideally development projects should protect areas that aren't going to be constructed/altered by staking these areas. For areas that are altered as a result for the construction process the City of Inver Grove Heights recommends the use of soil amendments to restore soil functions. Developments are required to preserve topsoil, restore soils by adding compost after construction, or implement other measures to maintain the soil's moisture holding capacity. There are economical ways to retain the benefits of healthy soil, and avoid more costly damage to streams, wildlife, and human health.

Function Within Stormwater Treatment Train

Soil amendments are one of the first steps in the treatment train. Rain that falls on amended soils has a better chance to infiltrate or filter through the soil than on graded soils, thereby reducing runoff volume. The practice may be applied as part of a stormwater management system to achieve one of the following objectives:

- reduce stormwater pollutants
- increase groundwater recharge
- decrease runoff peak flow rates
- decrease the volume of stormwater runoff
- preserve base flow in streams
- reduce thermal impacts of runoff.

Inver Grove Heights Stormwater Permit Applicability

One of the goals of this manual is to facilitate an understanding of and compliance with the City of Inver Grove Heights' volume control standard. This standard must be met on all new and re-development projects taking place in the northwest area.

The Inver Grove Heights stormwater permitting process allows reduction of graded curve numbers for pervious areas that have been amended. When the post-construction CN is calculated, the Hydrologic Soil Group does not have to increase after development because the soil compaction impacts have been negated. This serves the function of reducing the applicant's proposed condition volume, reducing the volume of infiltration required to meet the 5-year pre-post condition infiltration requirement. Chapter 9 includes a detailed example of using soil amendments in calculating runoff.

The following terms are thus used in the text to distinguish various levels of soil amendment design guidance:

REQUIRED:	Indicates design standards stipulated by the IGH PUD.
HIGHLY RECOMMENDED:	Indicates design guidance that is extremely beneficial or necessary for proper functioning of the practice, but is not specifically required by the City of Inver Grove Heights.
RECOMMENDED:	Indicates design guidance that is helpful for performance but not critical to the design.

Design Variants

Undisturbed Native Soil – Protect native soils from compaction during the construction phase.

Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface. “Manufactured” topsoil mixes should be weed free, making them ideal for seeding new lawns.

Native Soil – Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled and reapplied after grading or other construction disturbances are completed. Stockpiling may not be practical on small sites.

Disturbed Soil – Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas. Topsoil and forest duff excavated for structures and paved areas, or removed before site grading, can be stockpiled, reapplied after grading and amended.

Retrofit Suitability

Whenever projects involve grading or landscaping; soil amendments are a good choice for the retrofit. For example, soils can be amended before an area is resodded, seeded or whenever the current vegetation is going to be removed. Soil amendments are particularly desirable as retrofit practices in watersheds or catchments that are targeting volume reduction practices.

Cold Climate Suitability

Soil amendments do not have cold climate design limitations.

Water Quantity Treatment

The amount of stormwater volume reduction depends on the quality and care of the amended area during construction. Soil amendments reduce runoff by increasing the permeability of the soil. This permeability of the soil can be most effectively maintained by planting deep-rooted vegetation.

In general, supplemental stormwater practices will be necessary to satisfy the volume control requirements when soil amendments are used. However, these practices can help reduce volume requirements for a site through volume reduction and retention.

Water Quality Treatment

Soil amendments improve water quality through stormwater volume reduction and increased groundwater recharge.

Limitations

The following general limitations should be recognized when considering soil amendments:

- Limited monitoring data are available
- Initial cost is higher than not amending soils, although savings from stormwater infrastructure can offset this cost
- Area must be fenced off from construction traffic after soils are amended.

B. Major Design Elements

Physical Feasibility Initial Check

All vegetated areas are recommended for soil amendments. Including lawns, landscaping, perennials, annuals, and native plantings.

Conveyance

Stormwater is conveyed by runoff and infiltration.

Pretreatment

Soil amendments require no pretreatment but grassed channels, filter strips, and bioretention areas may use amended soils as part of a pretreatment practice.

Treatment

Space Occupied – None, soil amendments are a space saving bmp that requires no additional space. Soil amendments reduce the amount of runoff that needs to be treated, saving space in downstream BMPs.

- Practice Slope – May be used on any slope.
- Depth – The depth of soil amendments can range from 0” where native soils will be retained to 8” for amending soils in place. The depth is dependent on the type of amendment to be used.
- Aesthetics – Soil amendments are underground and are rarely seen. Surface effects of soil amendments may include healthier vegetation and better turf grass establishment.

Landscaping

- It is REQUIRED that the amended soil be established with dense and healthy vegetation as soon as possible after the soil is amended.
- It is HIGHLY RECOMMENDED that vegetation on amended soils be regularly maintained and bare areas seeded. Mowing can be used to maintain vegetation.

Safety

OSHA health and safety guidelines should be followed for safe construction practices. Additional information on safety for construction sites is available from OSHA. Use the following link to research safety measures for construction sites: http://www.osha.gov/pls/oshaweb/

Construction Details

No construction details for soil amendments are provided.

C. Construction Specifications

Amending soils incorporates techniques or steps which may be considered non-standard; it is RECOMMENDED that an engineer experienced in soil amendments be contracted for the final design plans and specifications.

I. Temporary Erosion Control
- ► Installation prior to site disturbance
- ► Catch basin/inlet protection
- ► Secure media with erosion control mat

II. Excavation, Backfill and Grading
- ► Timing of soil amendment
- ► Use of tractor or other equipment to till and amend soils
- ► Stockpiling location (if applicable)
- ► Restoration in the event of disturbance during construction

III. Native Plants, Planting and Transplanting
- ► Site preparation of planting areas
- ► Timing of seeding and planting
- ► Watering of plant material
- ► Weed control

IV. Construction Sequence Scheduling
- ► Varies based on design option (see design procedure)

V. Construction Observation
- ► Adherence to construction documents
- ► Continual site management
- ► Verification of physical site conditions
- ► Erosion control measures installed appropriately
- ► Completion of Construction

D. Operation and Maintenance

Amended soils can be treated the same as non-amended soils. Protecting amended soils from post-construction compaction will increase the soil's stormwater and horticultural benefits. Planting and maintaining native vegetation with deep roots will help maintain the organic composition of the soil and increase infiltration of stormwater.

Construction and Maintenance Costs

No construction and maintenance cost information has been developed to date.

E. Design Procedure

The five variants of soil amendments must be designed individually. The following steps guide the reader through the process needed to address soil amendments on the entire site. The construction sequence of each variant and the method of estimating the quantities of amendment follows.

These options can be used individually, or in combination (more than one may be used in different areas of a single site), so that they work best for the situation. The most convenient and economical methods for achieving the standards depends on site soil conditions, grading and subgrade compaction, practicality of stockpiling site topsoil during grading, and site access issues.

Choose Variant B, C, D and/or E to restore soil quality after construction in areas where grading and soil disturbance are unavoidable, and follow these requirements:

- ► Final soil depth should be a minimum of 8 inches.
- ► Avoid plowing or tilling within drip line of trees.
- ► Test soil pH, and if necessary, adjust to suit proposed plants.

Step 1. Review site conditions, landscape and grading plans

Examine site plans and soils. Use a shovel to dig in several areas that will be graded (or already have been) to determine if the newly exposed grades can be easily amended, or if compaction will require plowing/tilling of the subsoil or topsoil import. Determine if there are areas where soil could be stockpiled on-site.

Step 2. Select soil treatment variant and suitable pH for each planting area.

Amending with compost is often the most economical way to bring poor soils up to the required soil organic matter content. On sites with the original, undisturbed, native soil, and where space permits, stockpiling and reapplying topsoil may be less costly. Importing topsoil usually costs more than amending existing soil, though it may be easier where subsoil conditions make cultivation difficult.

Identify areas where soil can be: left undisturbed (Variant A), amended in place with compost (Variant B), removed and replaced with purchased topsoil (Variant C), or stockpiled and later reapplied (Variant D or E). Clearly outline those areas on the site plan and assign each area an identifying letter (A, B, C, D, or E) on the site drawing.

A) Undisturbed Native Soil – This variant is the most economical and best for the environment but not always feasible.

- ► Plan site development to leave areas where native vegetation does not need to be disturbed.
- ► Fence off areas of native vegetation on the site that will not be stripped, logged, or graded to protect them from disturbance during construction.
- ► Undisturbed areas do not require soil amendment.

B) Amend existing soils in-place – Where the soil has been compacted or the forest duff or topsoil removed, the simplest way to restore soil quality is to rototill compost into the existing soil.

- ► Apply a layer of compost to existing soil at the **amendment depth of 2.5 inches**. Use the worksheet in this chapter to calculate the amount of compost needed. *Retain copies of receipts for compost delivered to the site, as they will be used during inspection to verify the soil requirements have been met.*
- ► Rototill compost into soil to a depth of at least 8 inches. *Note that tilling to this depth will require repeated passes with a large machine, such as a tractor mounted or heavy rear tine rototiller.*

C) Import topsoil mix– Where subsoil is too rocky, compacted or poorly drained to amend effectively; a topsoil mix with 8 – 13% soil organic matter can be imported and placed on the surface.

- Import and apply a topsoil mix with 8 – 13% soil organic matter, which should contain 30 – 40% compost by volume, and clean sand or sandy soil. The soil depth should be 8 inches and the pH suitable for proposed plants. Ask topsoil suppliers for test results of their product to verify the material contains the desired organic matter content and pH. *Retain test result reports and receipts for material delivered to the site, as they will be used during inspection to verify that the soil requirements have been met.*
- For best results, plow or till compacted subsoil at least 2 inches deep before applying topsoil mix, and/or rototill some of the newly applied topsoil into the subsoil.

D) Native Soil: Stockpile site duff and topsoil; reapply after grading and construction – This design variant is only applicable to sites that have the original, undisturbed soil native to the site. This will most often be forested land that is being converted in the current project.

- Remove forest duff layer and topsoil and stockpile *separately, in an approved location prior to grading. Cover soil and duff piles with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow.*
- Reapply topsoil to landscape areas to a minimum 8 inch depth after grading and other disturbances are completed.
- For best results, plow or till compacted subsoil at least 2 inches deep before replacing stockpiled topsoil, and/or rototill some of the replaced topsoil into the subsoil.
- Apply a 2-inch layer of stockpiled duff as a mulch after planting.

E) Disturbed Soil: Stockpile topsoil, reapply and amend in place– This design variant is only applicable to sites where the soil is not the original, undisturbed soil native to the site. This will most often be unforested areas.

- Remove soil and stockpile in an approved location prior to grading. Cover soil with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow.
- Reapply stockpiled soil to landscape areas to a minimum 6 inch depth after grading and other disturbances are completed. In some cases, purchasing additional topsoil will be needed to achieve the 6 inch depth.
- Plow or till compacted subsoil at least 2 inches deep before replacing stockpiled soil, and/or rototill some of the replaced soil into the subsoil.
- Apply a layer of compost to the reapplied soil at a depth of 2.5 inches. Use the worksheet in this booklet to calculate the amount of compost needed. *Retain receipts for compost delivered to the site, as they will be used during inspection to verify the soil requirements have been met.*
- Rototill compost into soil to a depth of at least 8 inches. *Note that tilling to this depth will require repeated passes with a large machine, such as a tractor or heavy rear tine rototiller.*

Step 3. Calculate compost and/or topsoil volumes for each area.

- Calculate the square footage of each lettered area on site plan.
- Use the square footage figures to complete the Compost and Topsoil Calculation in Table 8.46. This will give you the amounts of topsoil and/or compost for 2.5 inch amendment depth in cubic yards needed to achieve the 8 inch soil depth.
- If there is less stockpiled site topsoil than the amount needed to achieve the 8 inch depth once reapplied, additional topsoil should be purchased to make up the difference. Subtract the cubic yards of site topsoil available to be stockpiled from the total amount needed to find the difference—the amount of additional topsoil that will need to be purchased.

Table 8.46. Compost and Topsoil Calculation

	A	B	C	D	E	F	G	H	I	
	Area 1 [SF]	Area 2 [SF]	Area 3 [SF]	Area 4 [SF]	Area 5 [SF]	Total Area (A+B+C+D+E) [SF]	Compost Multiplication Factor	Topsoil Multiplication Factor	Total Compost (F x G) [CY]	Total Topsoil (F x H) [CY]
Variant A							-	-		
Variant B							0.008	-		
Variant C							-	0.025		
Variant D							-	0.025		
Variant E							0.008	0.019		
								Totals [CY]		

Step 4. Identify compost and/or topsoils to be applied and retain records.

- ► Contact compost or topsoil sources and select products that meet the requirements, including 8 – 13% soil organic matter content for topsoil mixes and suitable pH for the proposed plants.
- ► Retain compost and/or topsoil product delivery tickets and test reports, as they will be used as verification records during inspection.

F. References

County Board of Supervisors of the County of Dane. 2005. Chapter 14 of the Dane County Code of Ordinances Regarding Erosion Control and Stormwater Management. Dane County, WI.

King County Department of Development and Environmental Services. 2005. Achieving the Post-Construction Soil Standard. King County, Washington.

CHEMICAL AND BIOLOGICAL TREATMENT



Tanners Lake alum injection facility - Oakdale, MN

Definition:
Chemical and biological treatment of stormwater enhances settling of suspended sediment by encouraging flocculation. Variations include aluminum sulfate, ferric chloride, chitosan, and polyacrylamide. Chemical and biological treatments are typically used as a final or polishing step in the treatment train.

KEY CONSIDERATIONS

Design Criteria:

- Properties of water to be treated (pH, sediment concentration, etc.)
- Level of treatment desired
- Requirements for discharge of treated water to receiving water bodies
- Type of facility required or present
- Pre-treatment or secondary treatment requirements
- Maintenance and monitoring requirements of the system

Benefits:

- Quickly removes suspended clays and silts
- Can be used as pre-treatment to remove suspended sediments prior to infiltration
- Can help project meet stringent water clarity and sediment-bound pollutant removal standards
- Suitable for cold climates

Limitations:

- Ongoing operation and maintenance of the chemical addition system may be required
- Monitoring may be required to determine the impact on downstream resources
- A pond or sediment collection area is necessary downstream of the treatment site for settling out the flocculants
- May require permit from DNR
- Expensive to build and operate

MANAGEMENT SUITABILITY

	Volume Control
	Peak discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
	Screening/ Filtration
	Temperature Control
X	Settling
	Evaporation
	Transpiration
X	Soil Adsorption
X	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
X*	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Bacteria
	Toxins - Hydrocarbon

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Chemical and biological agents such as aluminum sulfate, polyacrylamide, ferric chloride, and chitosan can be added to stormwater to encourage the settling of smaller suspended particles. In a typical detention pond, suspended clays and other small particles are not well removed because they require long detention times to settle out. The addition of chemical or biological agents allows the small suspended particles to group together to form a larger conglomerate particle (or flocculent) that rapidly settles out of the water column.

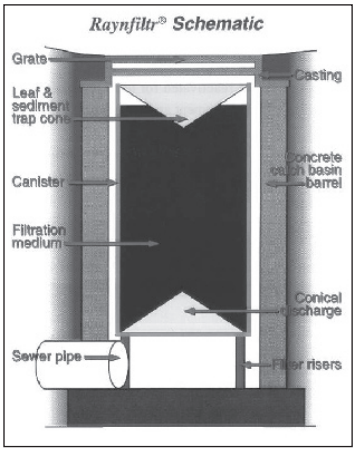
Chemical and biological treatment can be a passive system of flow through a solid form of the media, but it often requires the installation of monitoring and metering devices to ensure that the liquid agent is added at the proper dosage. Chemical or biological treatment can also be used as a temporary or one-time use product for construction or emergency situations.

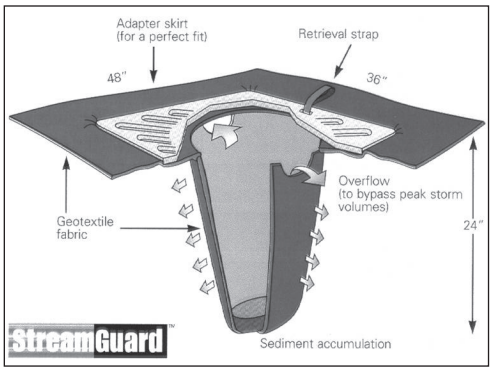
The City of Inver Grove Heights allows limited use of proprietary devices or “alternative methods”. Use of the alternative method must be approved by City staff prior to installation. Approval is limited to those methods that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method.

Selection:
When selecting or specifying a device that utilizes chemical or biological treatment processes, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What are the characteristics of the pollutants in the water used for testing? Review manufacturer’s protocols for testing.
3. Are the pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
4. Can the chemical or biological treatment agent be discharged into a natural water body?
5. What detention time is required for the chemical or biological treatment agent to cause flocculation?
6. How often must dosing rates be changed?
7. What are the construction costs? Does the cost include all materials, installation, and delivery?
8. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan?
9. Will the manufacturer provide design computations and CADD details?

FILTRATION DEVICES





Proprietary systems used as an example only - NOT an endorsement

Definition:
Filtration devices (inserts) allow stormwater to pass through filter media which are designed to reduce specific stormwater pollutants, but primarily solids and oils. Pollutants are captured physically or through sorption onto the filter media. Filters may either be inserts that are retrofitted into existing catch basins or manholes, or stand alone units supplied by a manufacturer.

KEY CONSIDERATIONS

Design Criteria:
- Pollutants of interest for reduction
- Desired removal efficiency
- Design flow or volume, site constraints on size, desired location of treatment unit
- Pre-treatment requirements
- Installation and maintenance costs, life of unit

Benefits:
- Units are typically underground or within existing structures and do not consume much site space
- Filtration devices can be customized to reduce a specific pollutant of concern
- Can often be easily incorporated into fully developed sites
- Can be used for pre-treatment prior to infiltration practices
- Relevant for use on industrial sites because filters can remove pollutants such as metals and oils

Limitations:
- Efficiency has not been widely tested
- Each type of unit has specific design constraints and limitations for use
- Can be more costly that other treatment methods
- Treatment may be greatly reduced if frequent maintenance is not conducted
- Subject to freezing in cold climates

MANAGEMENT SUITABILITY

	Volume Control
	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
	Settling
	Evaporation
	Transpiration
	Soil Adsorption
	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Coliform, Streptococci, E. Coli
	Toxins - Chloride, Hydrocarbon, Pesticide

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Filtration devices, depending on the design, can treat stormwater to reduce nutrients, sediment, floatables, metals, oil, and/or organic compounds. Different filtration media are used depending on the type of pollutant to be removed. Filter media may be a screen, fabric, activated carbon, perlite, zeolite, or other materials. Often a combination of filter media can be used to target the specific pollutants of interest.

These devices differ from the structural stormwater filters described earlier in Chapter 8 in two aspects. First, these devices are proprietary and are designed to fit as an insert into the hydraulic infrastructure (eg. a catch basin). Second, the media material may have unique characteristics which are different from the soil/sand media recommended for general stormwater filtration.

Filtration devices have been developed for use in locations such as underground chambers, catch basins, trench drains, and roof drains. The manufacturer specifications should indicate key design parameters such as size, allowable flow rate, allowable pollutant concentrations, and removal efficiency. A bypass should be part of the system to allow high flows to circumvent the filtration device.

Performance data are often provided by the manufacturer. Users should review this information to ensure it was provided by an independent source.

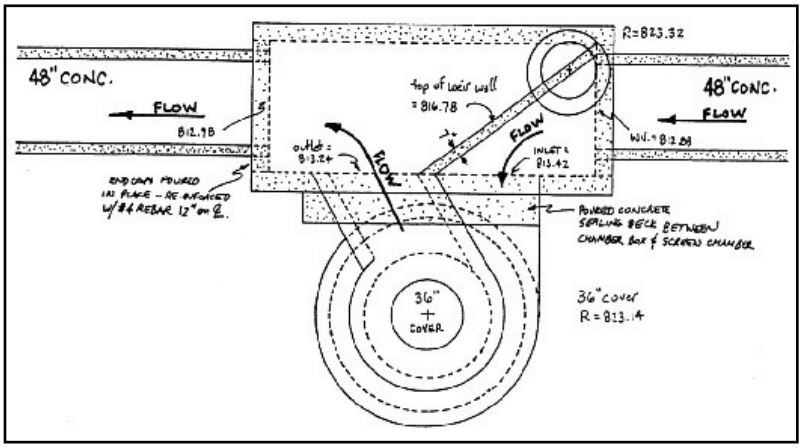
The City of Inver Grove Heights allows limited use of proprietary devices or “alternative methods.” Use of the alternative device as a stand alone BMP must be approved by City staff prior to installation. Approval is limited to those devices that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method. If a device does not meet this 80% total suspended solids removal requirement, then these devices could be used as pretreatment or supplemental to another stormwater practice.

Selection:
When selecting or specifying a filtration device, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What flow rates or volumes can the device accommodate? Will accessory structures be necessary to divert high flow around the filtration device?
3. What are the characteristics of the pollutants in the water used for testing? What particle size distribution was tested? Research protocols used for testing.
4. Are pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
5. Does the device contain a by-pass for high flows? If so, then what is the percentage of flow is prior to by-pass.
6. What are the construction costs? Does the cost include all materials, installation, and delivery?
7. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan? What is the typical life of the filtration unit?
8. Does the local regulatory authority approve the use of filtration devices?
9. Will the manufacturer provide design computations and CADD details?

SUPPLEMENTAL BMPs

HYDRODYNAMIC DEVICES



Courtesy of Minneapolis Public Works Department

Definition:
Hydrodynamic devices are designed to remove solids, oil/grease, floatables and other debris from stormwater runoff through gravitational trapping of pollutants. Typically used in combination with other structural BMPs, such as a pre-treatment device.

KEY CONSIDERATIONS

Design Criteria:

- Expected flow rates
- Pollutants of concern
- Desired removal efficiencies
- Site constraints for size
- Installation and maintenance costs, life of unit
- Need for accessory structures

Benefits:

- Units are typically underground and do not consume much site space
- Can often be easily incorporated into fully developed sites
- Can be used for pre-treatment prior to other practices
- Suitable for cold climates if installed below frost line

Limitations:

- Each type of unit has specific design constraints and limitations for use
- Treatment may be reduced if frequent maintenance is not conducted
- May not meet local standards when used alone
- Generally good for solids and litter, but much less effective for other common pollutants.

MANAGEMENT SUITABILITY

	Volume Control
	Peak Discharge/Rate Control
X	Water Quality/Pretreatment
	Wetland Bounce

MECHANISMS

	Infiltration
X	Screening/ Filtration
	Temperature Control
X	Settling
	Evaporation
	Transpiration
	Soil Adsorption
	Biological/ Micro. Uptake

POLLUTION REMOVAL

X*	Total Suspended Solids
	Nutrients - Total Phosphorus/ Total Nitrogen
X*	Metals - Cadmium, Copper, Lead, and Zinc
	Pathogens - Coliform, Streptococci, E. Coli
	Toxins - Chloride, Hydrocarbon, Pesticide

* target pollutants - actual percentage of pollutant removal varies with each device and installation

Description:
Hydrodynamic devices are chambers that allow sediment to settle out of the water column. The devices often enhance the rate of sediment settling through the circular motion of stormwater within the chamber. The devices also capture oil, grease, and other floatables, most often through the use of baffles. Hydrodynamic devices are typically designed to provide optimal removal efficiency for smaller, more frequent storms with minimal removal in larger, less common storms. To maintain removal efficiency, the devices require regular removal of accumulated sediment and floatables.

These devices are proprietary and typically are designed and installed by a manufacturer. Performance data are often provided by the manufacturer. Users should review this information to ensure it was provided by an independent source.

The City of Inver Grove Heights allows limited use of proprietary devices or "alternative methods." Use of the alternative device as a stand alone BMP must be approved by City staff prior to installation. Approval is limited to those devices that achieve approximately 85% removal of total suspended solids. Additionally, the City requires a two-year monitoring plan to measure the actual effectiveness of the method. If a hydrodynamic device does not meet this 80% total suspended solids removal requirement, then the device could be used as pretreatment or supplemental to another stormwater practice. No single, stand alone device has been found to meet this criteria.

Selection:
When selecting or specifying a hydrodynamic device, designers should research the following:

1. What are the minimum or maximum drainage areas recommended for the device or method?
2. What flow rates or volumes can the device accommodate? Will accessory structures be necessary to divert high flow around the hydrodynamic device?
3. What are the characteristics of the pollutants in the water used for testing? Research protocols used for testing.
4. Are pollutant removal tests verified by independent organizations such as USEPA, University of New Hampshire, University of Minnesota, Wisconsin Department of Natural Resources, or others?
5. Does the device contain a bypass for high flows? If so, then what percentage of flow is treated prior to bypass?
6. What are the construction costs? Does the cost include all materials, installation, and delivery?
7. What are the maintenance requirements? What are the costs of the required maintenance? Is there a standard operation and maintenance plan?
8. Does the local regulatory authority allow the use of hydrodynamic devices?
9. Will the manufacturer provide design computations and CADD details?

INVER GROVE HEIGHTS
Northwest Area

Chapter 9

Modeling Methodology and Example Design Procedure

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Modeling Methodology and Example Design Procedure

Chapter 9

this chapter of the manual is intended to serve as a guide for satisfying the stormwater management requirements of the Northwest Area (NWA) of Inver Grove Heights. To accomplish this task, a hypothetical development site has been created to demonstrate the steps that will need to be taken to meet these stormwater requirements

Contents

I. Description of Generic Development Site..... 3
II. Summary of Stormwater Management Requirements..... 3
III. Format of Chapter 9..... 5
IV. Pre-Development Analysis..... 5
V. Better Site Design (BSD) Analysis..... 12
VI. Post-Development Analysis..... 17
VII. Example Design Procedure Analysis..... 28
VIII. References..... 60

I. Description of Generic Development Site

The example development site, which will be referred to as Inver Grove Heights Meadows, is a 241-acre development that is broken into the following land uses:

Table 9.1 Land-Use Distribution for Inver Grove Heights Meadows		
Land-Use	**Acres**	**%**
Commercial	41.2	17.1
High Density Residential	55.7	23.1
Institutional	3.7	1.5
Low Density Residential	49.12	19.1
Natural Areas	59.3	24.5
Roads	35.5	14.6
Total	**241.3**	**100.0**

The layout of Inver Grove Heights Meadows has been developed to cover most, if not all of the design implications that could be encountered on a development site in the NWA. The development site contains a variety of land uses, it contains landlocked basins and wetlands of various management classifications, and it incorporates most of the BSD techniques and BMPs recommended in the manual.

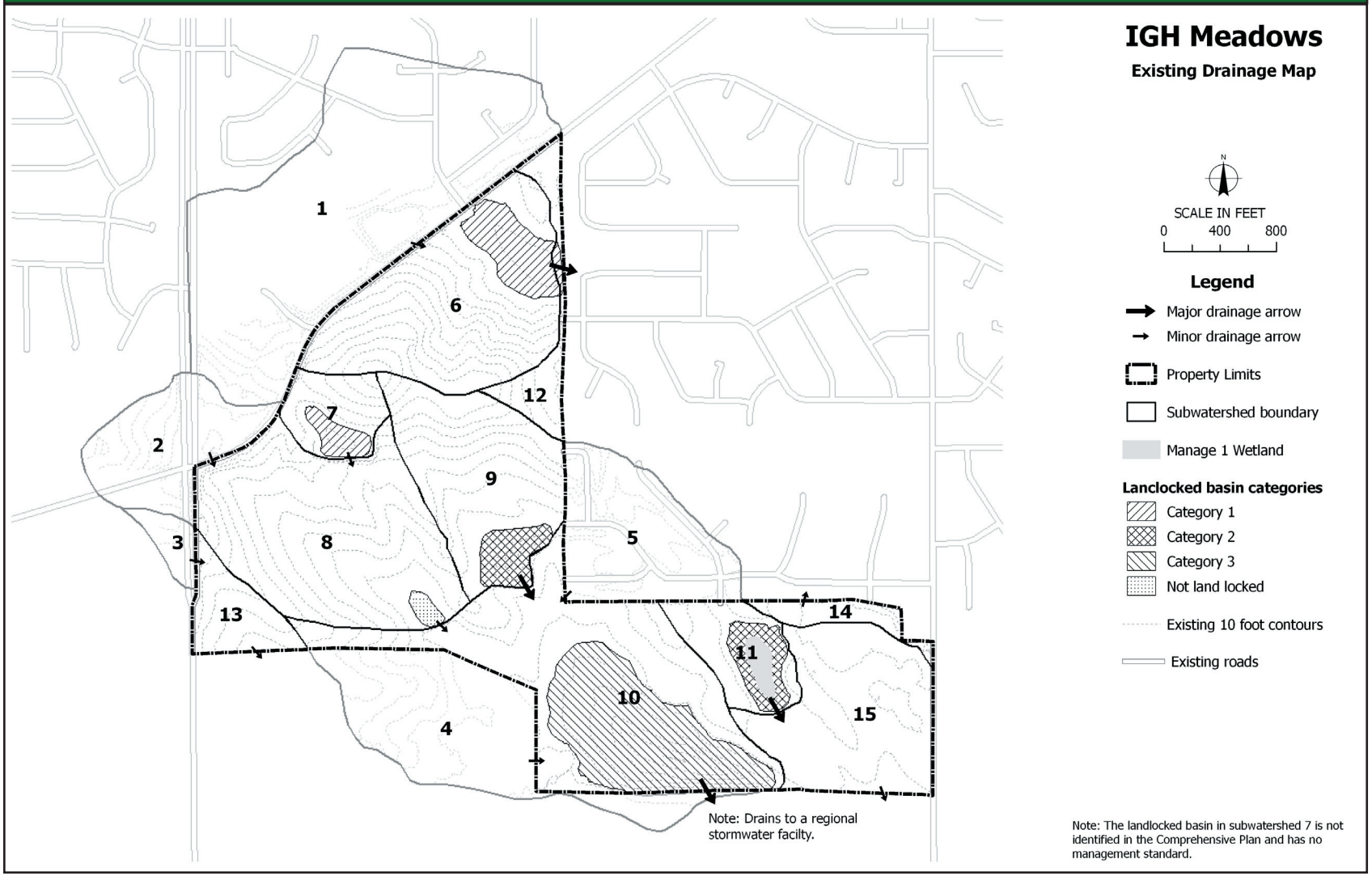
II. Summary of Stormwater Management Requirements

The example design procedure presented in this chapter, illustrates how a permit applicant in the NWA should perform stormwater calculations to meet the following stormwater management requirements:

Table 9.2 Summary of Stormwater Regulatory Requirements for the NWA	
Regulatory Requirements	**Regulatory Document**
Volume Control Standard - No increase in runoff volume from the site for the 5-year 24-hour rainfall event	NWA Planned Unit Development Overlay District
Pre-Treatment Standard	MPCA General Stormwater Permit for Construction Activity
Rate Control Standard - Rate control for the 2- and 10-year 24-hour rainfall events	Section 430 Inver Grove Heights Code
Minimum Building Low Floor Elevation Category 1 = Max. of HWL + 2 ft or NOF + 1 ft Category 2 - HWL + 6 ft Category 3 - HWL + 10 ft	Low Impact Development (LID): Overflow Contingencies and Cost Analysis
Wetland Bounce Standard – No increase in bounce for the 100-year 24-hour rainfall event for Manage 1 Wetlands and up to a half a foot of bounce for the 100-year 24-hour rainfall event for Manage 2 Wetlands.	Inver Grove Heights Natural Resource Inventory and NWA Planned Unit Development Overlay District

Figure 9.1 Inver Grove Heights Meadows Existing Conditions Drainage Map
Under existing conditions there are 15 subwatershed boundaries for Inver Grove Heights Meadows (see Figure 9.1). As the drainage arrows indicate, five of the subwatersheds contribute stormwater runoff from off-site areas, four of the subwatersheds drain to an off-site regional facility, and six of the subwatersheds are fully contained on-site.

SUBMITTAL REQUIREMENT: Provide map with existing conditions topography, drainage boundaries, and drainage arrows/ overflow points.



III. Format of Chapter 9

As mentioned previously, this chapter is meant to guide the design engineer through the steps required to meet the stormwater management requirements of the NWA. Given that most of the standards require matching pre-development or existing conditions for a given rainfall event, the general order of these calculations are as follows:

- ► Pre-Development Analysis
- ► Better Site Design Analysis
- ► Post-Development Analysis

For each of these analyses, the steps required to perform the analysis will be presented first, followed by the application to *Inver Grove Heights Meadows* (dark green callout box). Throughout the chapter, the design engineer will be notified of the City's submittal requirements (dark green callout box).

IV. Pre-Development Analysis

Step 1. Determine subwatershed boundaries and develop existing conditions drainage map.

Identify the subwatershed boundaries on an existing land use map based on the City's 2-foot topography (if still representative) or survey of the site. In some cases, subwatershed boundaries may extend off of the proposed development site. In these cases, this off-site stormwater contribution must be accounted for and included in the stormwater management plan and drainage calculations. In the event that a portion of the proposed development site is in a subwatershed that drains to an off-site regional stormwater management facility, the volume control standard will still need to be met locally.

Step 2. Develop surface water model to determine peak flow rate and runoff volumes for existing conditions.

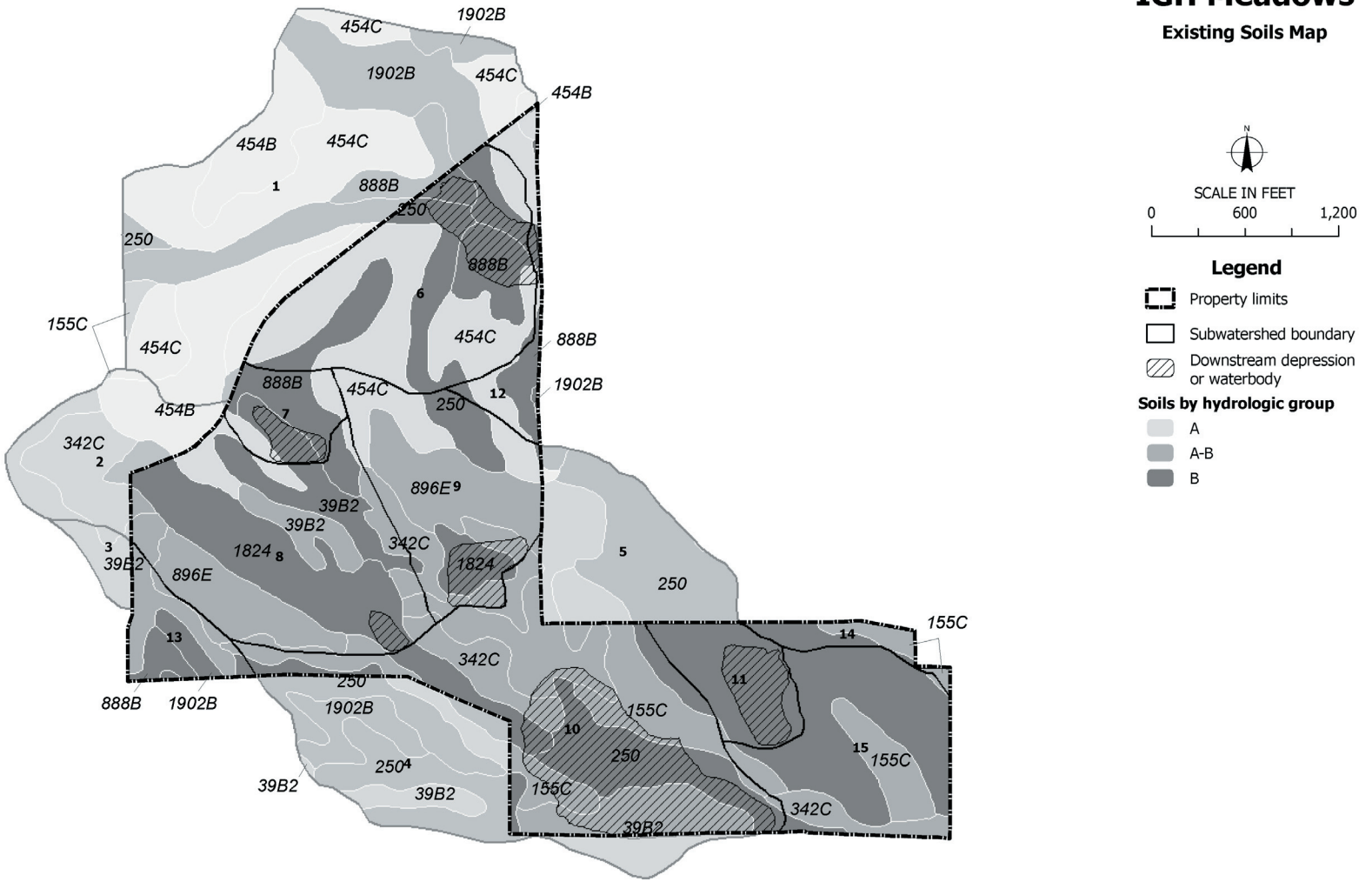
Stormwater calculations can be conducted using a TR-20 or Green-Ampt/Horton based hydrologic model (e.g. HydroCAD or SWMM). An electronic copy of the hydrologic model as well as the model report and design methodologies used for the determination of runoff and analysis of stormwater management practices shall be submitted to the City. The following steps provide guidance on the development of a TR-20 based hydrologic model.

A. Identify the soils located on site using the Dakota County Soil Survey. Given the map symbol for the soils, determine the corresponding Hydrologic Soil Group (HSG) for Inver Grove Heights using Table 9.3. Note that some soils have been assigned here an A-B classification since they have characteristics that are between A and B soils. On-site soil borings and classifications are good additional information that can be used and provided to modify the Dakota Soil Survey designations.

Table 9.3 NWA Soil Classification (HSG)		
Map Symbol	Soil Name	NWA HSG
177A,B,C	Gotham	A
283D	Plainfield	A
454B,C,E	Mahtomedi	A
611E	Hawick	A
7C,D	Hubbard	A-B
39B2	Wadena	A-B
129	Cylinder	A-B
155B,C,E	Chetek	A-B
342B,C,E,F	Kingsley	A-B
411A	Waukegan	A-B
415B,C	Kanaranzi	A-B
857A	Waukegan	A-B
858C	Chetek	A-B
889B,C,D	Wadena	A-B
	Hawick	A-B
896E,F	Kingsley	A-B
	Mahtomedi	A-B
49B	Antigo	B
94C	Terril	B
98	Colo	B
150B	Spencer	B
189	Auburndale	B
208	Kato	B
250	Kenebec	B
279B,C	Otterholt	B
313	Spillville	B
344	Quam	B
449B	Crystal Lake	B
539	Palms	B
861C	Kingsley	B
888B	Kingsley	B
895B,C	Kingsley	B
	Mahtomedi	B
	Spencer	B
1027	Udorthents	B
1029	Pits	B
1816	Kennebec Variant	B
1824	Quam	B
1902B	Jewett	B

Figure 9.2 Inver Grove Heights Meadows Existing Soils Map

SUBMITTAL REQUIREMENT: Provide map of existing condition soils, clearly labeling the NWA HSG for each map symbol (see Figure 9.2 for an example).



B. Determine the type of land cover that is present on the site based on the Natural Resource Inventory, recent aerial photographs and a site information. Land cover shall be classified as one of the following seven types: meadow; woods; woods & meadow; agricultural; urban open space (lawns and parks); wetland; and impervious surfaces (ponds, parking lots, roads, houses, etc.). Land cover shall be classified according to the definitions provided in Table 9.4.

Table 9.4 Land Cover Classification

Land Cover	Definition
Meadow	Greater than 85% of site vegetation consists of grasses
Woods	Greater than 85% of site vegetation consists of trees
Woods & Meadow	Combination of woods and meadow land cover with dominant cover consisting of less than 85% of total
Agricultural	Actively farmed land tilled for crop production
Urban Open Space	Lawns, parks, golf courses, etc. consisting primarily of turf grass
Wetland	Wetland as delineated by qualified professional
Impervious Surfaces	Paved surfaces, rooftops, open water, etc. where no infiltration of rainfall occurs

C. Assign curve numbers to each subwatershed given the soil type and existing land-use. Generally, the "Undisturbed" column of Table 9.5 should be used for pre-development modeling efforts and the "Graded" column should be used for post-development modeling efforts. Impervious surfaces (roads, houses, driveways, etc.) should be assigned a curve number of 98 while open water (ponds, lakes, etc.) should be assigned a curve number of 100. For more detailed information on how the curve numbers in Table 9.5 were established for the NWA see Appendix E.

D. Calculate composite curve numbers for each subwatershed. Open water surfaces may not be composited with the other areas. These surfaces will always be modeled as a separate subwatershed with a CN of 100.

Table 9.5 NWA Curve Numbers

Soil Type	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland
	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A-B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

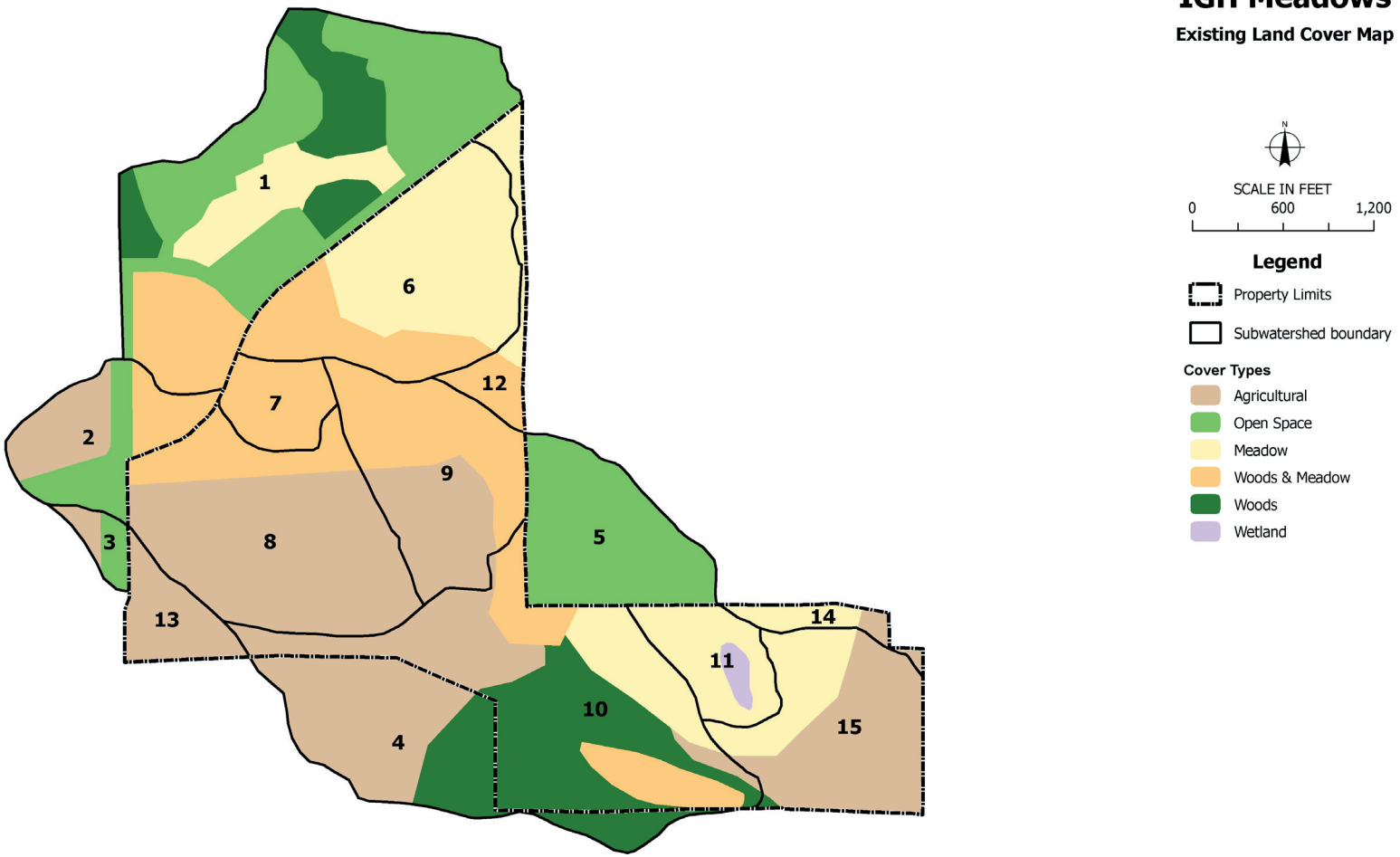
*Calculated average of A & B type soils, not found in MN Hydrology Guide

SUBMITTAL REQUIREMENT: Provide clear documentation of how curve numbers have been assigned.

E. Determine the Time of Concentration (T_c) for each subwatershed. The steps used to determine the T_c and the figures used to obtain the flow velocity based on slope and flow condition are provided in the Hydrology Guide for Minnesota (U.S. Department of Agriculture Soil Conservation Service St. Paul, Minnesota).

Figure 9.3 Inver Grove Heights Meadows Existing Land Cover
Under existing conditions, the development site for Inver Grove Heights Meadows consists of three primary land covers: agricultural, meadow, and woods & meadow. These land covers were classified using the definitions provided in Table 9.4. In addition, a wetland specialist identified and delineated one wetland on a site visit.

SUBMITTAL REQUIREMENT: Provide documentation of methods and sources used to determine site land cover.



F. Calculate existing peak flow for the 2-, 5-, 10-, and 100-year 24-hour rainfall events and total runoff volume for the 5-year rainfall event. Under pre-development conditions it is important to model or account for any natural ponding or depressions that may affect the amount and rate of runoff being flowed from the site. The rainfall depth in inches for the 2-, 5-, 10-, and 100-year 24-hour rainfall events for Inver Grove Heights are provided in Table 9.6:

Table 9.6 Rainfall Depths for the NWA

Recurrence Interval	Depth of Rainfall [inches]	Application of Analysis
2-year 24-hour	2.8	Rate Control
5-year 24-hour	3.6	Volume Control
10-year 24-hour	4.2	Rate Control
100-year 24-hour	6.0	Flood, Bounce & Duration Rate

Step 3. Evaluate basin interconnectivity and emergency overflow (EOF) requirements for each of the subwatersheds delineated in Step 1.

Identify the type of depression or water body located in each of the subwatersheds impacted by the proposed development site and determine the corresponding management standards. The depressions and water bodies in the NWA have been grouped into three categories based on the elevation difference between the outlet of the depression or water body and the existing conditions critical high water level of that depression or water body. The classification of each depression or water body critical event HWL can be found in the Comprehensive Plan Amendment.

As the *Technical Memorandum to the Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies & Cost Analysis* describes, a downstream depression or water body will fall under one of the categories outlined in Table 9.7.

Table 9.7 NWA Landlocked Basin Management Categories

Management Category	Definition*	Description
Category 1	NOF-HWL is between 0 – 6 feet	No additional infrastructure to be provided. Preserve existing natural overflow.
Category 2	NOF-HWL is between 6 – 18 feet	To ensure limitation of property damages in the event of extreme flooding, an emergency back-up outlet will be constructed for basins in this category.
Category 3	NOF-HWL is greater than 18 feet	A contingency overflow and location must be identified and an easement must be provided along the potential drainageway.

*NOF = natural overflow (elevation at which a landlocked basin would overflow)
HWL = high water level (as provided by City or updated by applicant's modeling)

Table 9.8 Inver Grove Heights Meadows Landlocked Basin Categories				
Subwatershed Basin No.	Critical Event HWL	Outlet Elevation	Management Category	Outlet Management Standard
6	945.4’	951.0’	1	No change
7	1,023.7’	1,027.0’	1	N/A*
8	952.2’	951.0’	Not Landlocked	N/A*
9	954.6’	961.0’	2	Overflow drop structure at the HWL + 4 feet.
10	919.9’	939.0’	3	No change
11	938.9’	945.0’	2	Overflow drop structure at the HWL + 4 feet.
*NOTE: These two basins are not identified in the Comprehensive Plan. Check with City Engineering Division for management standards.				

SUBMITTAL REQUIREMENT: Provide a map and table that identify all landlocked basins and clearly identify the Management Category (Table 9.7) for each basin. See Figure 9.1 for an example of how the landlocked basins can be identified on the existing conditions drainage map.

Step 4: Identify on-site and downstream wetlands by management classification.

The City of Inver Grove Heights has prioritized the protection of wetlands located within the City. The wetlands are classified into four categories, Manage 1, 2, 3, and 4 (NRI, October 2003). The classification of any wetland is provided in Chapter 2, Figure 2.10.

As mentioned previously, a wetland delineation identified one wetland on the development site. Using Figure 2.10 it is apparent that the wetland is a Manage 1 wetland. As figure 9.1 illustrates, this wetland is located at the bottom of landlocked basin 11. The management requirement for this water body will be to maintain the 100-year 24-hour HWL at or below existing or pre-development conditions.

Table 9.9 Wetland Management Requirements	
Wetland Classification	Management Requirements [100-year rainfall event]
Manage 1	Maintain HWL and duration at or below existing conditions
Manage 2	Maintain HWL and duration at or below existing conditions plus 0.5 feet
Manage 3	No requirement
Manage 4	No requirement

SUBMITTAL REQUIREMENT: Provide a map that identifies the management requirements of all wetlands located on site and those that are downstream (off-site) receiving water bodies. See Figure 9.1 for an example of how the wetland management classification can be identified on the existing conditions drainage map.

Step 5. Summarize the results of the pre-development analysis.

Develop a table with the following information to be used in a comparison with post-development conditions: subwatershed identification, area (acres), composite curve number, time of concentration (minutes), peak flow rates for the 2-, 5-, 10-, and 100-year 24-hour events and runoff volumes for the 5- and 100-year 24-hour events. The HWL for Manage 1 or 2 wetlands should also be shown.

Table 9.10 Inver Grove Heights Meadows Pre-Development Results

Sub-Watershed I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
1	76.4	43	10-12	6.8	21.9	37.5	97.6	3.30	-
2	18.6	46	24-35	0.0	0.5	1.1	9.1	0.19	-
3	3.2	50	24-35	0.0	0.2	0.5	2.5	0.06	-
4	31.2	52	24-35	0.4	2.9	7.1	28.4	0.73	-
5	23.7	57	24-35	2.2	8.1	14.3	38.5	1.07	-
6	40.4	38	24-35	0.0	0.0	0.0	0.0	0.02	-
7	8.8	42	24-35	0.0	0.0	0.0	0.0	0.04	-
8	45.7	52	24-35	0.0	0.4	1.4	13.7	1.07	-
9	29.8	42	24-35	0.0	0.0	0.0	0.0	0.12	-
10	55.9	43	24-35	0.0	0.0	0.0	0.0	0.29	-
11	11.5	49	24-35	0.0	0.0	0.0	0.0	0.19	934.1
12	7.5	38	24-35	0.0	0.0	0.0	0.8	0.01	-
13	8.6	55	24-35	0.3	1.5	3.0	9.8	0.27	-
14	4.2	45	24-35	0.0	0.1	0.2	1.8	0.04	-
15	29.2	52	24-35	0.3	2.8	6.8	27.1	0.70	
TOTAL	394.5	-	-	-	-	-	-	-	-

SUBMITTAL REQUIREMENT: Show pre-development results including at a minimum all the results shown in the table above.

V. Better Site Design (BSD) Analysis

During the early stages of the concept plan development, the design engineer should incorporate all of the Better Site Design (BSD) techniques required in the Northwest Area Planned Unit Development Overlay District (PUD) as well as any others that may reduce the volume of stormwater runoff generated under post-development conditions.

This section of the Example Design Procedure identifies the BSD techniques that an applicant is required to incorporate on the development site. This section also makes recommendations for including additional BSD techniques that will reduce the volume of stormwater runoff generated on site thereby reducing the volume requiring mitigation. For a more detailed explanation of all of the BSD techniques and their application see Chapter 4 of this Manual.

Step 1. Determine how to incorporate the REQUIRED Better Site Design (BSD) techniques on the proposed development site.

The following BSD techniques are required in the PUD (note that these requirements are grouped in the same manner they are presented in Chapter 4 of the Manual).

In general, these BSD techniques result in a reduction in the amount of imperviousness on site and a corresponding reduction in the stormwater runoff volume requiring mitigation. For most of these BSD techniques, the SUBMITTAL REQUIREMENT will be to appropriately identify the BSD technique(s) in the construction plans and specifications. For those techniques that require additional information, the specific SUBMITTAL REQUIREMENTS will be provided in a call-out box.

Preserving Natural Areas

- **At least 20% of the buildable development area within the PUD shall be preserved as additional natural area/open space**, which may include greenways as shown in the City of Inver Grove Heights Natural Resources Inventory and Management Plan (BRAA, 2003). Natural area/open space shall be designated in the following priority order (identify these areas in relation to the proposed project site):

  i. Protect steep slopes in those subwatersheds that have a significant portion of their drainage area covered in slopes of 25% or greater (see the steep slope map located in Chapter 2, Figure 2.9);

  ii. Incorporate public trails or public open space designated in the Comprehensive Plan. This would be in addition to any land that would be used to satisfy the public park dedication requirement found in the City's Subdivision Ordinance (Section 510);

  iii. Protect natural features such as slopes of 25% or greater, and environmentally sensitive areas and scenic features of the site identified as Manage 1 or 2 resources or priority sites in the City of Inver Grove Heights Natural Resource Inventory and Management Plan for the Northwest Expansion Area (BRAA, 2004);

  iv. Create natural area/open spaces in and around neighborhoods. This priority is satisfied by providing continuity of adjacent natural area/open space corridors or parkways; network of interconnected natural area/open space corridors; or buffers between incompatible or conflicting land uses."

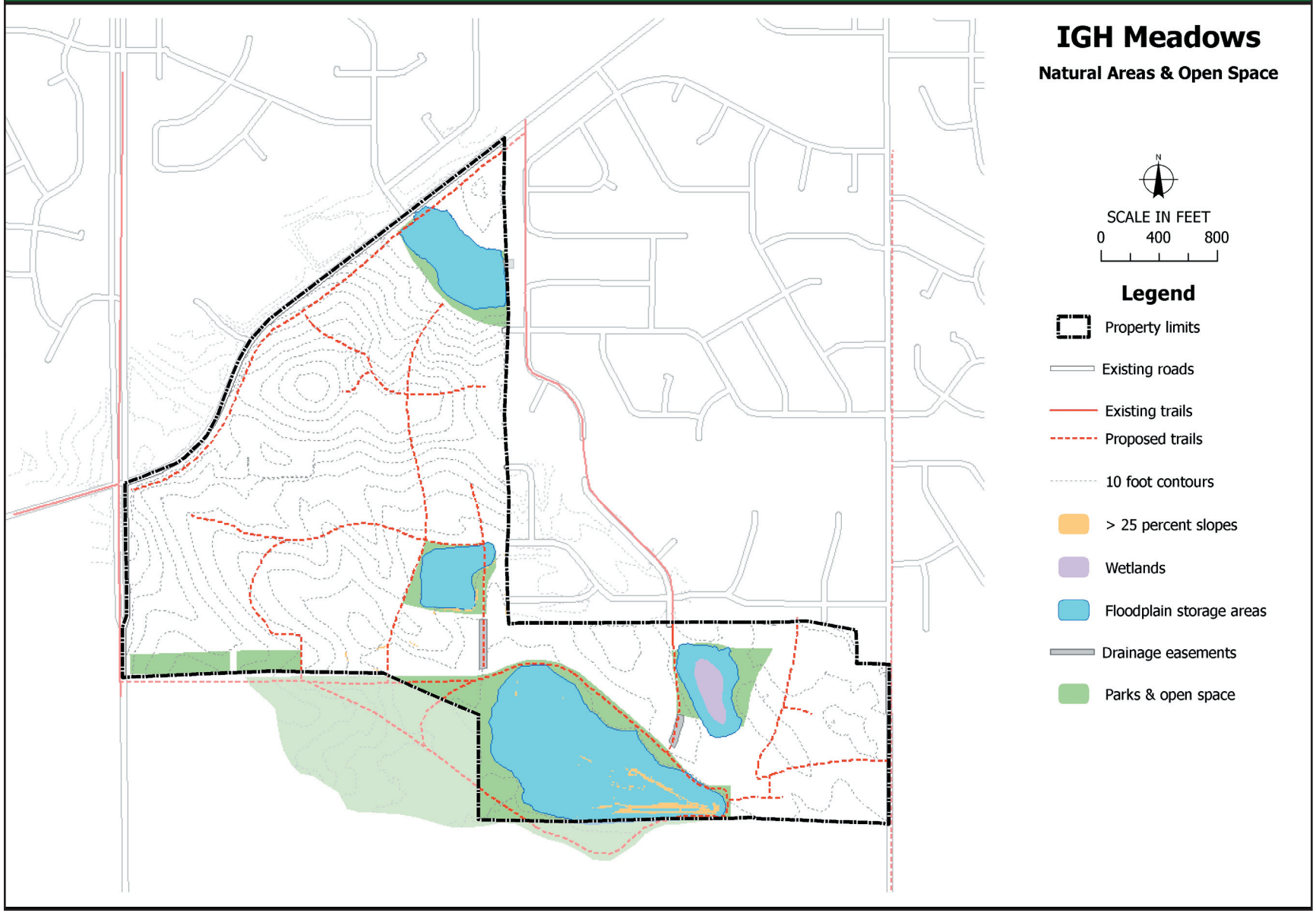
At least 75% of the natural area/open space shall be contiguous with no portion less than 100 feet wide, unless otherwise approved by the City Council.

At least 50% of the 20% of the natural area/open space shall be maintained in a natural, undisturbed condition with natural plant materials and shall not be graded or improved with any building, structure or other impervious surface except: 1) public utilities; 2) limited access in the form of a paved walking or hiker/biker path, the total impervious area of which shall not be more than 2% of the total natural area/open space; and 3) unless otherwise approved by the City Council.

The remaining 50% of designated natural area/open space may be used for passive or active recreation or the location of stormwater management features. If used for active recreation, impervious cover shall not exceed 5% of the remaining area.

Figure 9.4 Inver Grove Heights Meadows Natural Area Requirement Map

SUBMITTAL REQUIREMENT: Provide a map that clearly identifies the areas that meet the 20% natural area/open space designation and the classification of the natural area (see Figure 9.5 for an example).



The allocation of natural area/open space for Inver Grove Heights Meadows is illustrated in the following table:

Table 9.11 Natural Area/Open Space Requirement Allocation	
Natural Area Priority	**Total Percentage of Land**
i. – Subwatershed Steep Slopes	0.5%
ii. – Public Trails	6%
iii. – Natural Feature Protection	21%
iv. – Open Spaces	Not required (20% already attained)

Disconnecting and Distributing Runoff

- **Parking lot curbs shall either be flat or have breaks at regular intervals** to convey runoff into the stormwater system. The use of flat curbs or curbs with regular breaks can be used with filter strips to meet the pretreatment requirements identified in Chapter 6 of this Manual.

- Surface **parking lots in excess of 100 spaces shall provide landscaped islands** between double loaded rows of parking. Such landscaped islands shall also serve as a stormwater cell (see Stormwater Landscaping section of Chapter 4). The stormwater cell can act as a pretreatment measure or as a BMP. If it is to be used as a BMP, the appropriate length of filter strip must be provided as described in Chapter 6 of this Manual.

- Residential **downspouts and sump pumps shall flow to cisterns and/or permeable surfaces** (non-residential downspouts shall do the same when feasible). If a downspout is used, the flow may be pretreated by the vegetated surfaces. If cisterns are used for watering gardens and regularly drained, they can be used to meet the pretreatment requirement and as a direct runoff volume reduction (assume cistern is empty for stormwater calculations).

SUBMITTAL REQUIREMENT: For applications larger than a residential rain barrel, applicant must submit a plan for water usage and demonstrate adequate storage volume.

Reducing Impervious Cover in Site Design

- **Local public streets shall have a 28 foot paved width** in addition to a sidewalk or trail on one side of the street. This street dimension shall restrict parking to only one side of the street. See Chapter 4 for a proposed street cross-section.

- **Cul-de-sacs** shall be designed with a turn-around having an **outside roadway radius of 35 feet and a street property line (ROW) radius of 50 feet**. Cul-de-sacs can be designed with larger diameters provided a landscaped island is included and designed for stormwater storage.

- **Driveway widths for single-family detached residential dwellings, two family and twin home dwellings shall be no more than 20 feet**. In all other cases it shall be no more than 32 feet.

- 50% of total parking required for Multi-Family and Mixed Use development shall be **underground parking, tuck-under parking or structured parking** within or under the principal structure.

- **Pervious paving materials** shall be used for that portion of parking over the minimum required off-street parking spaces. For more information on pervious surfaces, see Chapter 9 of this Manual. In general, the losses resulting from the use of pervious systems should be modeled using information provided by the manufacturer or retailer of the product. If the system is sufficiently pervious, it should be modeled as a dry pond with the void ratio of the fill material.

- Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of **permanent pervious surface**. See comments regarding the application of pervious systems in previous bullet.

Step 2. Evaluate the feasibility of incorporating additional RECOMMENDED BSD techniques to further reduce the volume of stormwater runoff generated under post-development conditions

The following BSD techniques are recommended to reduce the volume of stormwater generated on site, requiring mitigation (note that these requirements are grouped in the same manner they are presented in Chapter 4 of the Manual).

In general, these BSD techniques result in a reduction in the amount of imperviousness on site and a corresponding reduction in the stormwater runoff volume requiring mitigation. For most of these BSD techniques, the SUBMITTAL REQUIREMENT will be to appropriately identify the BSD technique(s) in the construction plans and specifications. For those techniques that require additional information, the specific SUBMITTAL REQUIREMENTS will be provided in a call-out box.

SUBMITTAL REQUIREMENT: For site reforestation or prairie restoration, the applicant will be required to submit a landscaping and vegetation management plan that at a minimum identifies responsible parties, duration of management, and acceptable maintenance activities.

Preserving Natural Areas

- Site Layout to avoid sandier soils (A, A-B) and wooded and/or meadow areas.

- Site Reforestation or Prairie Restoration (see Chapter 4 for a more detailed explanation of this BSD technique). The application of this technique will reduce runoff volumes due to the application of lower curve numbers applied to woods or meadow land cover (see Table 9.5).

SUBMITTAL REQUIREMENT: To apply this technique, the application will be required to submit a compost amendment of tilling plan that contains the following information: site plan identifying areas where soil treatment will be applies and any stockpiling or staging areas; brief written description of which soil treatment options will be used on site; compost and topsoil calculations demonstrating the amount of compost and/or topsoil to be imported.

Disconnecting and Distributing Runoff

- Soil compost amendments or tilling (see Chapter 4 for more detail on the application of this technique). The stormwater benefit of applying soil amendments or tilling is that the volume of runoff generated on site is reduced. To reflect this reduction in the stormwater calculations, the applicant will be allowed to select a CN value from Table 9.5 that reflects "undisturbed" conditions versus the "graded" conditions CN.

Reducing Impervious Cover

- Shared driveways (see Chapter 4 for more detail on the application of this technique).

- Single-family residential driveways constructed of pervious materials such as pavers, pervious concrete or pervious asphalt. For more information on pervious surfaces, see Chapter 9 of this Manual. In general, the losses resulting from the use of pervious systems should be modeled using information provided by the manufacturer or retailer of the product. If the system is sufficiently pervious, it should be modeled as a dry pond with the void ratio of the fill material.

VI. Post-Development Analysis

This section walks the applicant through the post-development analysis. At this point, the pre-development rates and volumes entering the downstream water bodies/landlocked basins have been determined and Better Site Design (BSD) techniques aimed at reducing stormwater runoff volume have been incorporated in proposed (post-development) site layout.

As the post-development drainage map (Figure 9.5) illustrates, there are a number of additional subwatersheds under the post-development scenario: 25 versus 15 under pre-development conditions. In order to illustrate the design approach recommended to meet the City's stormwater management standards, five subwatersheds have been selected for this example calculation. These examples have been selected to illustrate the application of most of the BSD techniques and BMPs recommended in this Manual. These examples, which can be found at the end of the Post-Development Analysis, re-iterate the design steps described below.

Step 1. Determine subwatershed boundaries and develop post-development conditions drainage map.

Identify the subwatershed boundaries on the proposed conditions (post-development) grading plan. In some cases, subwatershed boundaries may extend off of the proposed development site. In these cases, this off-site stormwater contribution must be accounted for and included in the stormwater management plan and drainage calculations. In the event that a portion of the proposed development site is in a subwatershed that drains to an off-site regional stormwater management facility, the volume control standard will still need to be met locally.

In general, development in the NWA should maintain existing hydrologic boundaries and flow to landlocked basins. In the event that the existing hydrologic boundary is modified under proposed (post-development) conditions, the applicant will be required to review the potential impacts of this change with the City early in the planning process. Alterations in the hydrologic boundary may impact the HWL for the critical event (the 100-year 10-day snowmelt event).

Figure 9.5 Post-Development Drainage Map
Under proposed conditions there are 25 subwatersheds versus 15 subwatersheds under pre-development conditions. The existing hydrologic boundaries are maintained and all stormwater flow points remain the same.

SUBMITTAL REQUIREMENT: Provide map with post-development conditions drainage boundaries and contour lines.

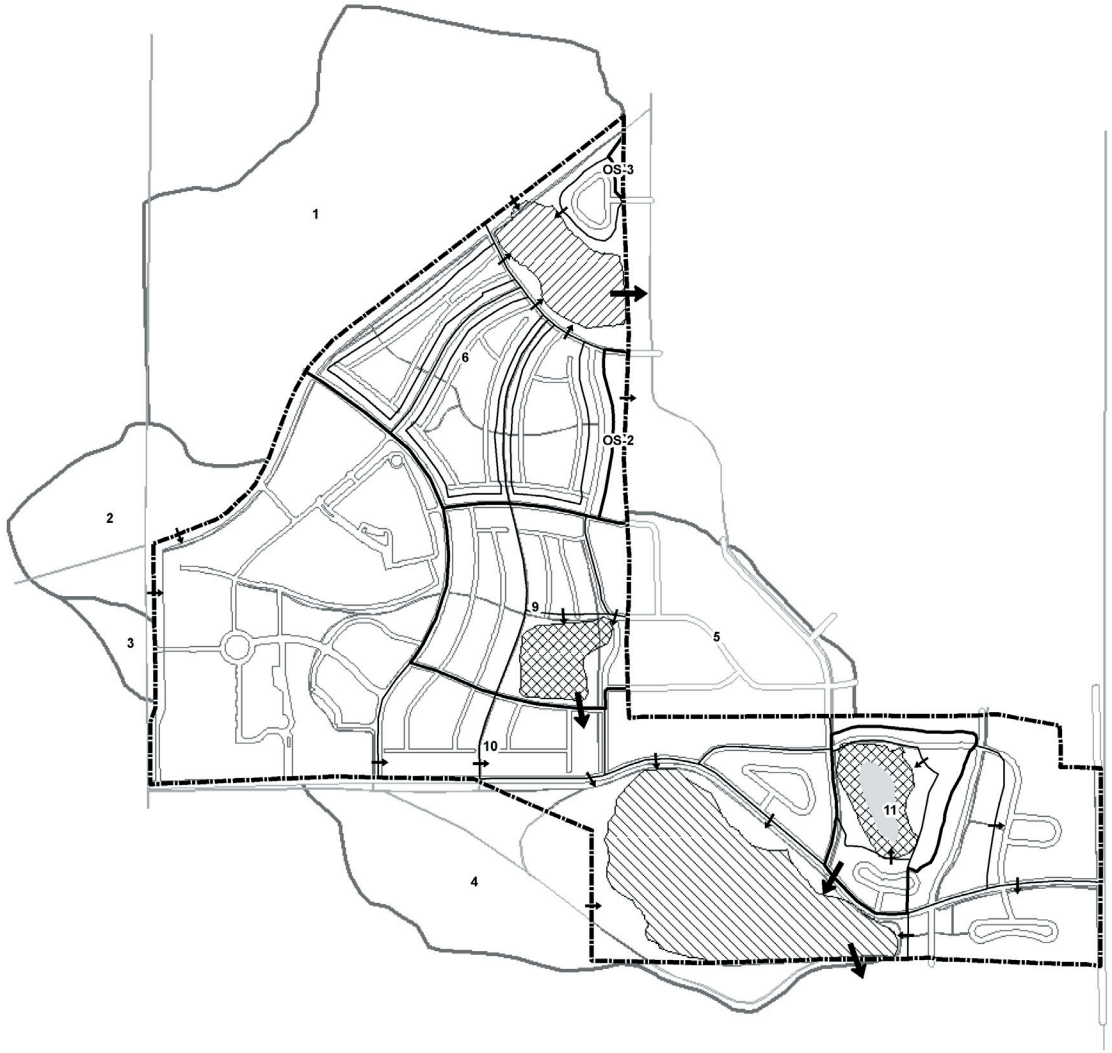
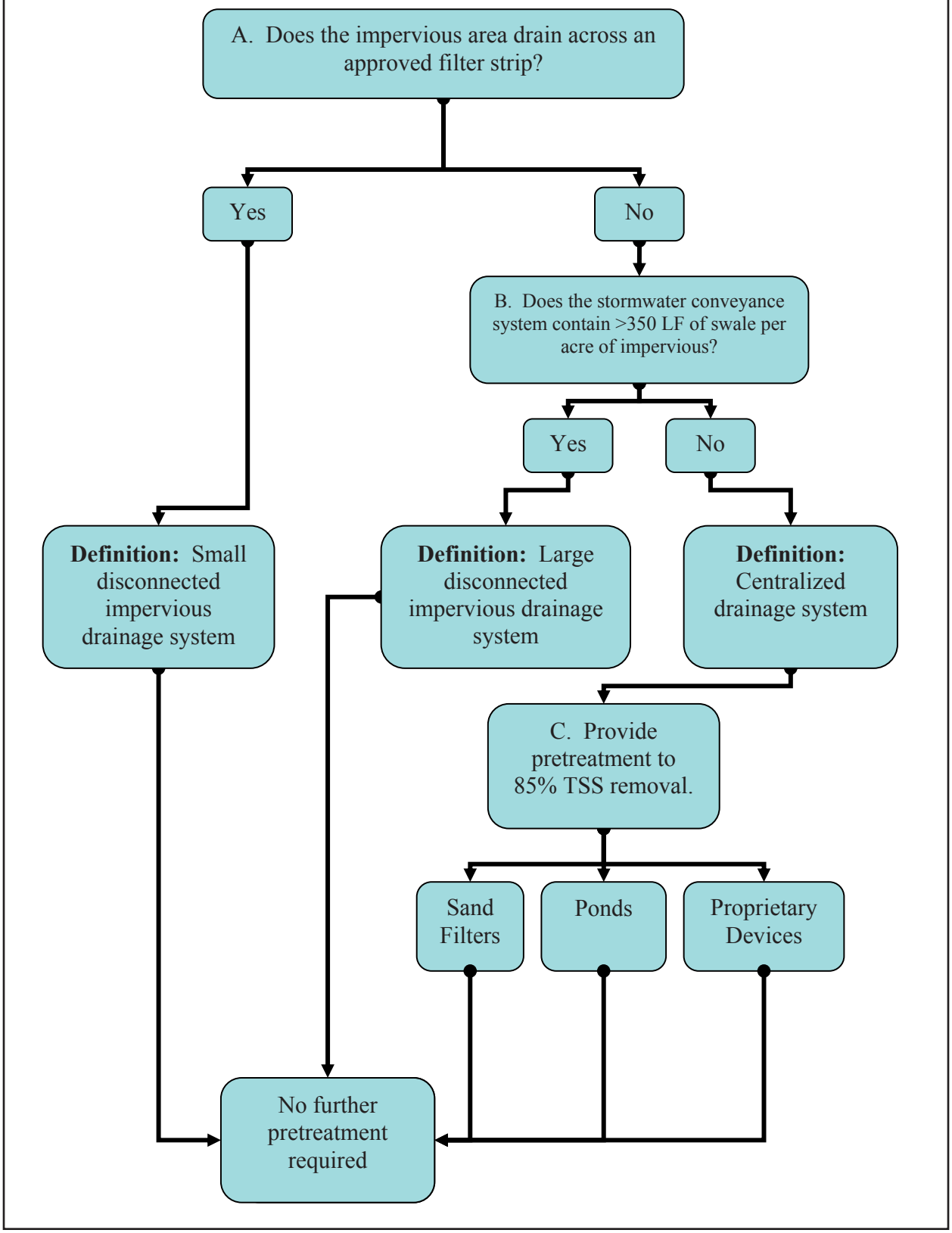


Figure 9.6 NWA Pretreatment Flow Chart



Step 2. Determine pretreatment requirements and design pretreatment measures.

The amount of pretreatment required depends upon the type of drainage system that is being used to convey stormwater runoff to the BMP. Figure 9.6 (introduced in chapter 6) should be used with the corresponding text to define the type of drainage system that is being used and decide where structural pretreatment devices are necessary. The three types of drainage systems are 1) "small disconnected drainage system", 2) "large disconnected drainage system" or 3) "centralized drainage system". Drainage systems 1 and 2 do not require any additional pretreatment devices because pretreatment is met through disconnection of impervious surfaces. Drainage system 3 requires the use of a BMP to accomplish the 85% TSS removal requirement.

A. Identify all impervious areas that flow over an approved filter strip.

There are two general situations that filter strips satisfy the pretreatment requirement. Areas that fall under this category do not need to provide additional pretreatment. Situations not covered here will require approval by city engineering staff.

- Impervious areas less than 0.25 acre that drain across grass filter strips with the dimensions shown in Table 9.12 (Introduced in chapter 6) or greater have already met the pretreatment requirement and require no further pretreatment. Use the Table 9.12 to find the necessary length of filter strip. The purpose of this drainage system distinction is to recognize pretreatment for disconnected impervious areas such as rooftops that drain through yards, or crowned driveways, patios, sheds and other small areas of imperviousness that drain over large pervious areas before entering the stormwater system.

Table 9.12 Filter Strip Sizing

Parameter	Impervious Parking Lots & Streets				Rooftops			
Inflow Approach Length [ft.]	0-35		>35		0-35		>35	
Filter Strip Slope	<2%	2-5%	<2%	2-5%	<2%	2-5%	<2%	2-5%
Filter Strip Minimum Length	10'	15'	20'	25'	10'	12'	15'	18'

- Filter strips may be used as pretreatment for lineal infiltration practices such as infiltration trenches along roadways. The roads, filter strip, and infiltration practices must be designed to allow sheet flow from the road through the filter strip before the runoff enters the infiltration practice. If water is to be concentrated and channelized then the drainage area is considered connected and additional pretreatment is necessary.

To establish that the impervious area falls into this category, it is helpful to examine the impervious/pervious interface. If more then 0.25 acres drains to the pervious area across any one point then the impervious surface is NOT a small disconnected impervious drainage system. The dimensions in Table 9.12 must also be met.

- Small disconnected impervious areas must be shown on the site plan and can be excluded from sizing of pretreatment facilities.

B. Identify all areas that are part of a large disconnected impervious drainage system

- If the drainage area to the infiltration BMP is conveyed through vegetated swales or buffers, the BMP is considered a large disconnected drainage system. Large disconnected impervious systems meet

the pretreatment requirement through filtering in vegetative channels but must contain at least 350 LF of channel per acre of impervious. Large disconnected impervious systems generally exist in areas developed with rural road cross-sections where stormwater is conveyed through grassed channels and/or swales.

► Large disconnected impervious areas must be shown on the site plan and can be excluded from sizing of pretreatment facilities.

C. Design Filter, Pond, or Proprietary device to remove 85% TSS for remaining impervious drainage area. The remaining impervious area is classified as a centralized drainage system.

► Identify the remaining impervious area on the site plan. This is the runoff area that you should use to size pretreatment facilities.

► Use the following sizing criteria for pretreatment facilities. Other practices may be allowed at the city engineer's discretion.

Sand Filters

An operation and maintenance plan must be made to ensure that sand filters are adequately maintained to provide pretreatment.

Recommendations:

► Use an 18-inch thick filter bed
► Use a sand media with a coefficient of permeability of 3.5 ft/day (1.75 in/hr)
► Set the maximum head on the filter to 6 feet
► Drain the filter bed within 72 hours, 48 hours if need to meet MPCA permit requirements

The filter area for a sand filter that has the recommended characteristics can be sized based on the following equation.

$$A_f = 0.0476 * V_{wq}$$

The filter area for a non-standard filtration system is sized using the following equation (based on Darcy's Law).

$$A_f = (V_{wq})\ (d_f) \ / \ [(k)\ (h_f + d_f)\ (t_f)]$$

Where:

A	=	Surface area of filter bed (ft^2)
V_{wq}	=	Water quality volume (ft^3)
df	=	Filter bed depth (ft)
k	=	Coefficient of permeability of filter media (ft/day)
h_f	=	Average height of water above filter bed (ft)
t_f	=	Design filter bed drain time (days)

SUBMITTAL REQUIREMENT: Provide a map that clearly distinguishes between impervious surfaces that satisfy the pretreatment requirement with filter strips (small disconnected drainage system) and those impervious surfaces that utilize other pretreatment methods (large disconnected or centralized drainage systems). Provide calculations that exhibit how the pretreatment standards are being met. Also identify all structural pretreatment features (swales, sand filters, proprietary devices, etc.) on the map and provide typical details for each pretreatment feature in the plan set.

Ponds
- ► Design to NURP standards
- ► Permanent Pool Volume =1800 CF/Acre of Drainage
- ► Permanent Pool Depth = 3' – 10'

Proprietary Devices
- ► Must meet a 85% TSS removal using standard particle size distribution
- ► Must have a means to remove floatables and grease
- ► Must have a maintenance plan for removing sediments

Step 3. Develop surface water model to determine peak flow rate and volume of runoff being generated for the 5-year, 24-hour rainfall event.

Develop the hydrologic model for the 5-year, 24-hour rainfall event to determine the stormwater runoff volume that the Best Management practices (BMPs) are being designed to handle. As the City's PUD states, there shall be no increase in runoff volume from the site for the 5-year 24-hour rainfall event. Stormwater calculations can be conducted using a TR-20 based hydrologic model (e.g. HydroCAD). An electronic copy of the hydrologic model as well as the model report and design methodologies used for the determination of runoff and analysis of stormwater management practices shall be submitted to the City. The following steps provide guidance on the development of a TR-20 based hydrologic model.

This hydrologic model will generate peak flow rates and volumes that will be compared to pre-development conditions. The rate and volume comparison will be made at the nearest landlocked basin or water body, or the point at which the runoff leaves the development site.

A. Identify the soils located on site using the Dakota County Soil Survey. See Figure 9.1 and Step 1A under the pre-development analysis for more detail.

B. Determine the type of land cover that is present on the site based on the Natural Resource Inventory, recent aerial photographs or a site survey. Land cover shall be classified as one of the following seven types: meadow; woods; woods & meadow; agricultural; urban open space (lawns and parks); wetland; and impervious surfaces (ponds, parking lots, roads, houses, etc.). Land cover shall be classified according to the definitions provided in Table 9.4.

SUBMITTAL REQUIREMENT: Provide clear documentation of how curve numbers have been assigned. If soil amendments or tilling are used the application will be required to submit a compost amendment of tilling plan that contains the following information: site plan identifying areas where soil treatment will be applies and any stockpiling or staging areas; brief written description of which soil treatment options will be used on site; compost and topsoil calculations demonstrating the amount of compost and/or topsoil to be imported.

C. Use Table 9.5 to assign curve numbers given the soil type and post-development condition land-use of the site (see highlighted columns in Table 9.5). If land has not been graded, or soil amendments have been utilized, use curve numbers provided in "Undisturbed" column. (See Chapter 8 for soil amendment details.) All impervious surfaces are to be assigned a curve number of 98. Ponds/open water are to be assigned a curve number of 100.

Figure 9.7 Inver Grove Heights Meadows Proposed Conditions (Post-Development) Soils Map

SUBMITTAL REQUIREMENT: Provide map of post-development condition soils, clearly labeling the NWA HSG for each map symbol.

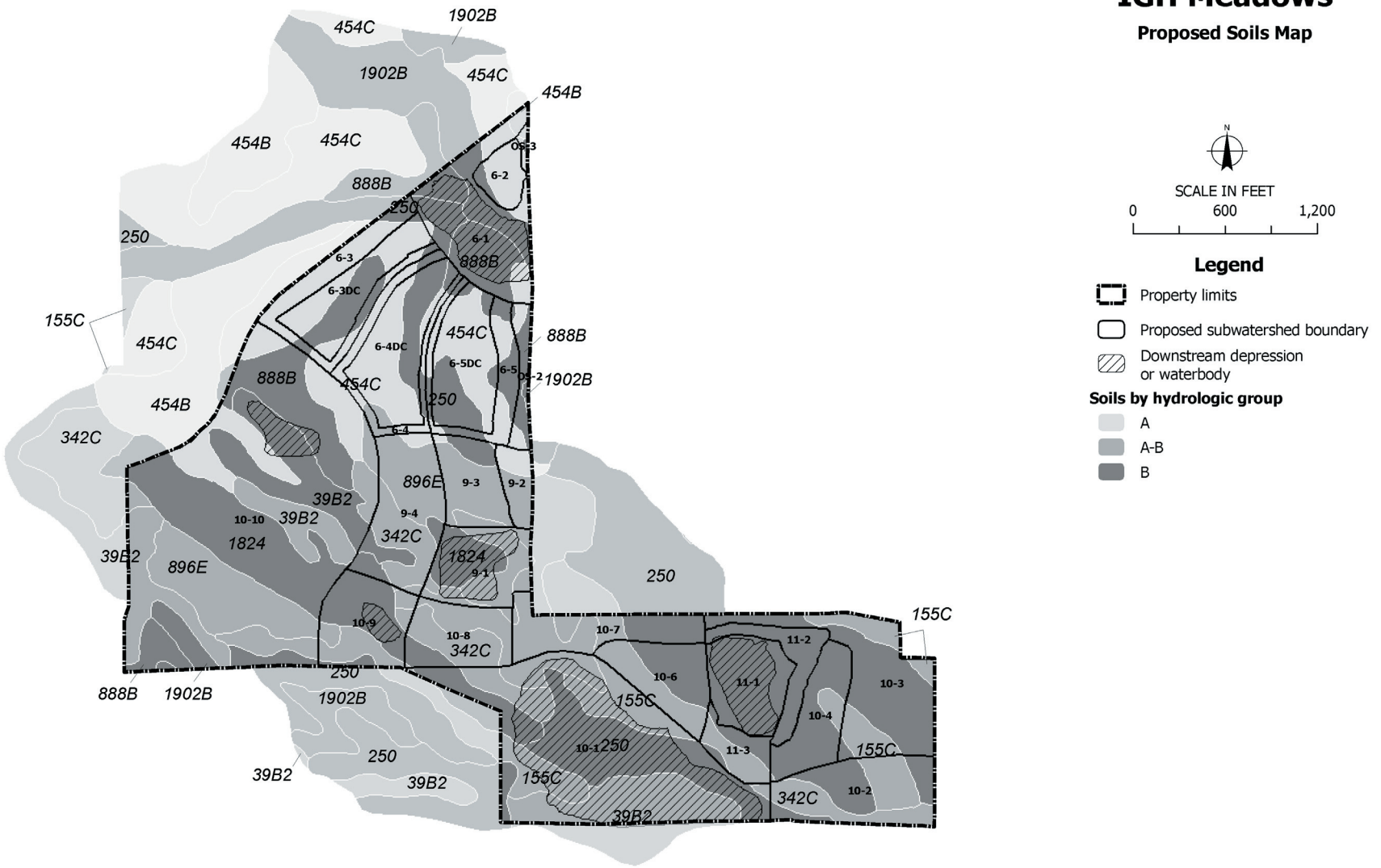


Figure 9.8 Inver Grove Heights Meadows Proposed Conditions (Post-Development) Land Cover
Under proposed conditions, the development site for Inver Grove Heights Meadows consists primarily of the following land uses: institutional, commercial, multi-family residential, single-family residential and open space.

SUBMITTAL REQUIREMENT: Provide documentation of methods and sources used to determine site land cover.



D. Calculate composite curve numbers for each subwatershed.

The pretreatment analysis conducted in Step 2 will be very useful in developing the model to calculate the peak flow rates and runoff volumes. The total impervious area for the site should be determined and divided into two categories: impervious area pretreated by filter strips (small disconnected drainage system); impervious area pretreated by other structural features (large disconnected or centralized drainage systems). These categories will be used to determine whether or not the impervious surface curve numbers may be composited with the pervious curve numbers or not.

Small Disconnected Impervious Drainage Systems – The pervious surfaces in the subwatershed should be composited with the impervious surface curve numbers (except for open water which must always be modeled separately).

Large Disconnected and Centralized Drainage Systems - The impervious surfaces that are pretreated by structural features other than filter strips should be modeled as a separate subwatershed with a curve number of 98 or greater (pond curve number = 100). Be sure to include all ponding areas as impervious surfaces for this calculation.

E. Determine the time of concentration for each subwatershed. The steps used to determine the T_c and the figures used to obtain the flow velocity based on slope and flow condition are provided in the Hydrology Guide for Minnesota (U.S. Department of Agriculture Soil Conservation Service St. Paul, Minnesota).

F. Calculate preliminary post-development peak flow and total runoff volume for the 5-year, 24-hour rainfall events and determine runoff volume for treatment. A comparison of the pre- and post-development volumes (post-development volume minus pre-development volume) will determine the volume of stormwater runoff that needs to be infiltrated on site. By meeting this requirements, other requirements established by agencies (e.g. Minnesota Pollution Control Agency) will be met or exceeded.

Step 4. Design Stormwater Best Management Practices (BMPs).

The specific design criteria for each of the BMPs that can be used to meet the City's volume control standard are provided in Chapter 8 of this Manual. These BMPs include:

- Bioretention
- Infiltration
- Green Roofs
- Pervious Surfaces
- Rainwater Harvesting
- Stormwater Ponds
- Stormwater Wetlands

While this detail of designing specific BMPs is provided in Chapter 8 of this Manual, the example calculations provided at the end of this section walk the applicant through the process for most of the BMPs. In general, the design of a stormwater BMP is an iterative process that involves performing the following steps:

A. Make a preliminary judgment as to whether site conditions are appropriate for the use of the BMP, and identify the function of the practice in the overall treatment system

- Consider basic issues for initial suitability screening including: site drainage area; site topography and slopes; soil infiltration capacity; regional or local depth to groundwater and bedrock; site location / minimum setbacks.

- ► Determine how the BMP will fit into the overall stormwater treatment system – will this be the only BMP employed or are there other BMPs addressing some of the treatment requirements and where on the site the bioretention practice is most likely to be located.

B. Perform field verification of site suitability

C. Select design variant based on Physical Suitability Evaluation

Given the runoff volume and the drainage area, select the appropriate BMP for the first iteration of the design process. Guidance on applicable BMPs given a certain drainage area is provided in Chapter 8 of this Manual.

Information collected during the site suitability evaluation should be used to explore the potential for multiple infiltration practices versus relying on a single infiltration facility. The use of smaller BMPs dispersed within a development is usually more sustainable than a single regional facility that is more likely to have maintenance and groundwater mounding problems (WDNR, 2004).

D. Size BMP

E. Size outlet structure and/or flow diversion structure, if needed

F. Perform groundwater mounding analysis (as necessary depending upon the type of BMP being evaluated)

Step 5. Summarize the results of the post-development analysis.

After the BMP sizing iterative process has been completed, analyze the 2-, 10-, and 100-year, 24-hour rainfall event for peak flow rates. Once calculated, develop a table comparing the following information to pre-development conditions: subwatershed identification, area (acres), composite curve number, time of concentration (minutes), peak flow rates for the 2-, 5-, 10-, and 100-year 24-hour events and runoff volumes for the 5-year, 24-hour event. The HWL for Manage 1 or 2 wetlands should also be shown. If any modifications are proposed to the hydrologic boundaries, the overflow elevations, the outlet elevations, or if grading occurs within the regional basins, a critical even analysis must be performed. This includes modeling the back-to-back 100-year, 24-hour rainfall event as well as the 100-year, 10-day snowmelt event.

As seen in Table 9.13 and Table 9.14, all applicable peak flow rates and volumes decrease or remain the same moving from existing to proposed conditions. Table 9.15 summarizes pre- vs. post-development conditions. Because hydrologic boundary sizes do not significantly change, the critical event analysis was not conducted.

Table 9.13 Inver Grove Heights Meadows Post-Development Results

I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
6-2	2.35	70	14	0.0	0.0	0.1	2.9	0.0	-
6-3	12.24	*1	*1	0.0	0.0	0.8	3.9	0.0	-
10-10	79.07	*1	*1	0.0	1.1	5.9	23.2	0.63	-
11-1	7.2	52*2	30	0.1	0.5	1.6	6.5	0.17	934.0’

Table 9.13 Inver Grove Heights Meadows Post-Development Results									
I.D.	Area [ac]	CN	Tc [min]	Peak Flow Rate 2-yr event [cfs]	Peak Flow Rate 5-yr event [cfs]	Peak Flow Rate 10-yr event [cfs]	Peak Flow Rate 100-yr event [cfs]	Runoff Volume 5-yr event [AF]	HWL 100-yr event [ft]
11-2	3.13	*1	*1	0.0	0.0	0.0	0.3	0.0	-
*1 more than one subwatershed, therefore more than one CN and T_c *2 composite CN of 52 not used for calculations, see 11-1 step 3C for details									

Table 9.14 5-year Pre- to Post-Development Peak Flow Rate and Volume Comparison							
Landlocked Basin	Subwatershed	Peak Flow Rate into Regional Basin [cfs]	Total Proposed Peak Flow Rate [cfs]	Peak Flow Rate from Existing Conditions [cfs]	Volume to Basin [ac-ft]	Total Proposed Volume [ac-ft]	Volume from Existing Conditions [ac-ft]
6	1 (OS)	1.4	1.4	1.8	1.52	1.52	1.54
	2	0.0			0.00		
	3	0.0			0.00		
	4	0.0			0.00		
	5	0.0			0.00		
	6	0.0			0.00		
9	1	0.1	0.2	0.2	0.02	0.10	0.12
	2	0.0			0.00		
	3	0.0			0.02		
	4	0.1			0.06		
10	1	0.2	12.3	14.6	0.14	2.57	3.32
	2 (OS)	2.9			0.73		
	3 (OS)	8.1			1.07		
	4 (OS)	-			-		
	5	0.0			0.00		
	6	0.0			0.00		
	7	0.0			0.00		
	8	0.0			0.00		
	9	0.0			0.00		
	10	1.1			0.63		
11	1	0.5	0.5	0.5	0.17	0.17	0.19
	2	0.0			0.00		
Off-Site	1 (OS)	0.2	1.0	4.5	0.06	0.25	1.07
	2	0.3			0.04		
	3	0.5			0.15		

	Output from example shown
	Onto site from off-site (doesn't change)
	Output from model

NOTE: In existing conditions subwatersheds 1 and 6 drain to Basin 6, subwatersheds 2, 4, 5, 7, 8, 9, and 10 drain to Basin 10, while Basins 9 and 11 receive only subwatersheds 9 and 11, respectively. Subwatersheds 3, 12, 13, 14, and 15 drain off-site.

Figure 9.9 Inver Grove Heights Meadows Proposed Conditions Drainage Map

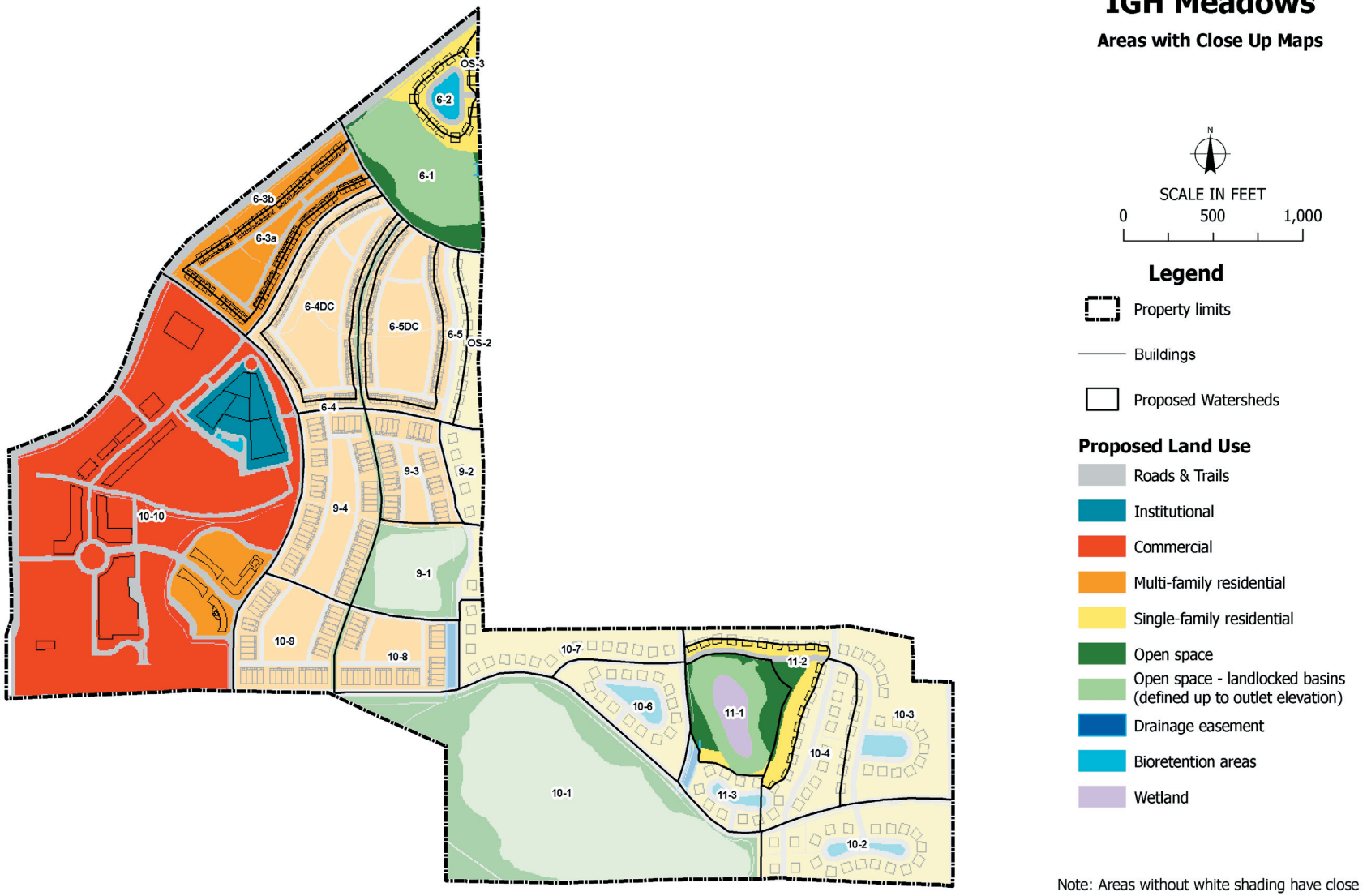


Figure 9.10 Example Calculation Summary for Subwatershed 6-2

Landuse(s): Low Density Residential
Pretreatment Feature(s): Filter Strips
BMP(s): Depressed Island and Soil Amendments

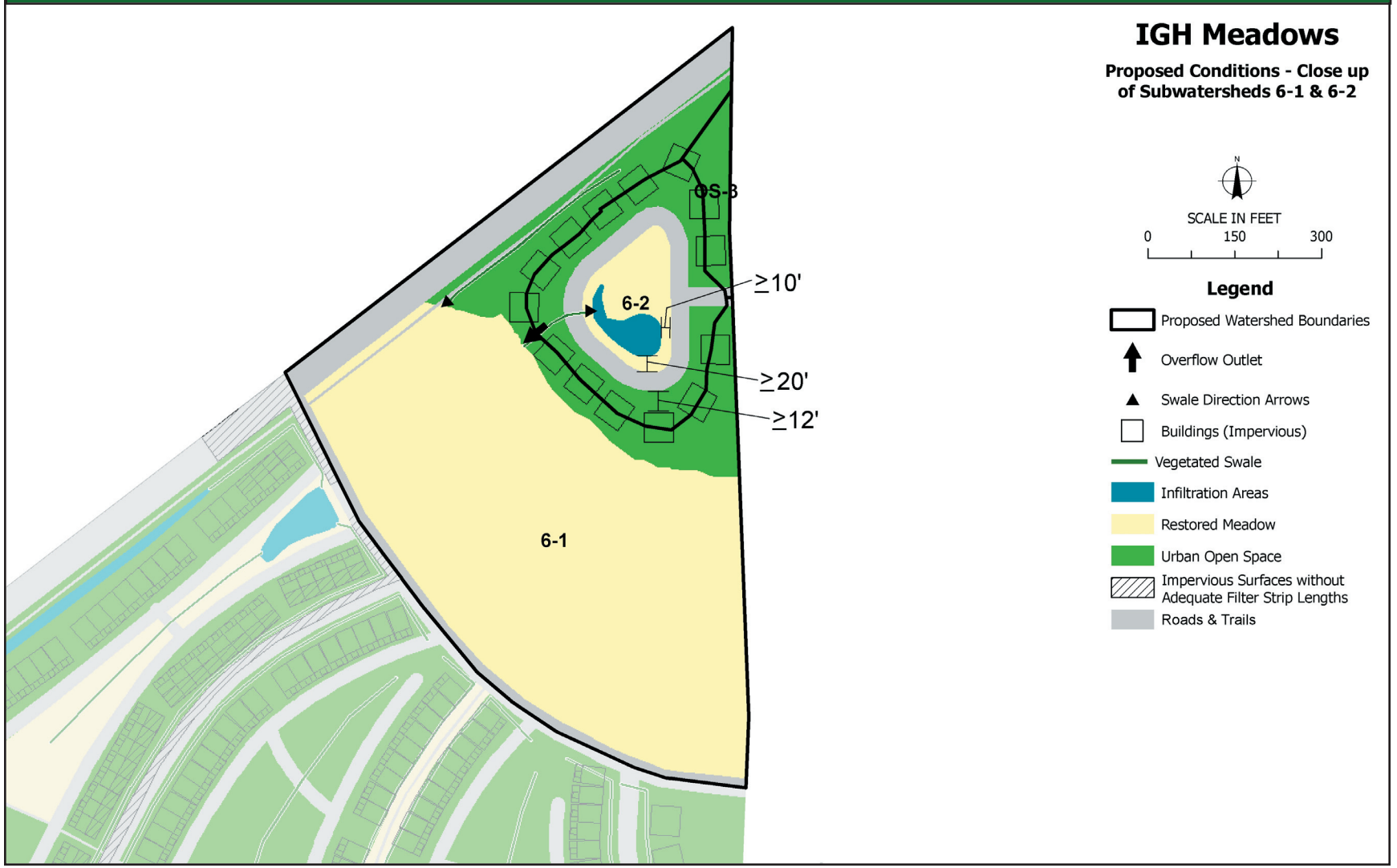


Table 9.15 Peak Flow Rate Comparison for Pre- to Post-Development Conditions								
Land-locked Basin	2-yr Peak Flow Rate [cfs]		10-yr Peak Flow Rate [cfs]		100-yr Peak Flow Rate [cfs]		100-yr HWL [ft]	
	Proposed	Existing	Proposed	Existing	Proposed	Existing	Proposed	Existing
6	0.1	0.1	3.1	3.2	9.6	11.0	-	-
9	0.0	0.0	0.3	0.5	6.8	8.0	-	-
10	2.3	2.4	20.9	34.6	74.1	136.6	-	-
11	0.1	0.1	1.6	1.5	6.5	8.0	934.0’	934.1’
OS	0.2	0.6	9.2	9.4	35.5	41.8	-	-

SUBMITTAL REQUIREMENT: Post-development results including at a minimum all the results shown in Table 9.15. The post-development results must also be clearly compared to the pre-development results, showing that the 2-, 10-, and 100-year peak flow rates and 5-year runoff volumes into the landlocked basins do not increase.

VII. Example Design Procedure Analysis

The following analysis shows how Inver Grove Heights Meadows was designed to effectively meet all of the City’s stormwater requirements. As Figure 9.9 illustrates, the development site is comprised of institutional, commercial, multi-family residential, single family residential and open space. It also illustrates the final number of subwatersheds and drainage paths under post-development conditions.

Table 9.16 Subwatershed 6-2	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	All of the developed area in subwatershed 6-2 is graded to flow into the depressed BMP located in the center of the entrance road loop. Houses - Each house has its rooftop runoff directed over the front lawn which acts as a **filter strip** with at least 12 feet (3% slopes) of length before reaching the roadway, satisfying the pretreatment standard in Table 9.12. Roads - The roadway drains to the bioretention area. The roadway is 20 feet wide and runs off to a flat **filter strip** (1% slope), requiring a length of 10 feet. This is exceeded for the entire roadway. Driveways - The driveways are not crowned and flow directly onto the street and then to the bioretention area. The driveway length must be added to the roadway length for Table 9.12 calculations, resulting in a **filter strip** length requirement of at least 20 feet (1% slope). The filter strip was lengthened in order to meet this criteria and now satisfies the pretreatment requirement.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage systems on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Table 9.16 Subwatershed 6-2

Step	Action
	Filter strips were used to satisfy all of the pretreatment requirements. Therefore the impervious surface curve number (CN) may be composited with the CNs of the pervious surfaces. Therefore this site is modeled with one subwatershed with the CNs composited into one CN. All of the lawns have undergone a soil amendment following the procedure described in Chapter 8 allowing the use of the "urban open space, natural condition" CN found in Table 9.5. The area inside of the road loop will be a meadow buffer with soil amendments modeled using the CN in the column "meadow and woods, natural condition".

Subwatershed	Soil Type	Land Cover	Acres	CN
6-2	-	Impervious (FS)	1.19	98
6-2	A	Meadow	0.64	33
6-2	A	Urban Open Space	0.18	39
6-2	B	Urban Open Space	0.32	61
			2.35	**70**

	For this subwatershed, there are 1.16 acres of pervious surfaces with a combination of A and B soils, and 1.19 acres of impervious surfaces with a curve number of 98. After compositing (see above table), the subwatershed runoff parameters were a CN of 70 for 2.35 acres.
D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 14 minutes for this subwatershed.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.11).
C	**Select design variant.**

Table 9.16 Subwatershed 6-2

Step	Action
	The drainage area to the BMP is approximately 1 acre in size. Using the information presented in the following table, the depressed island (bioretention) appears to be the most suitable option for meeting the City's volume control requirements.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**

Figure 9.11 Example Soil Boring for Subwatershed 6-2

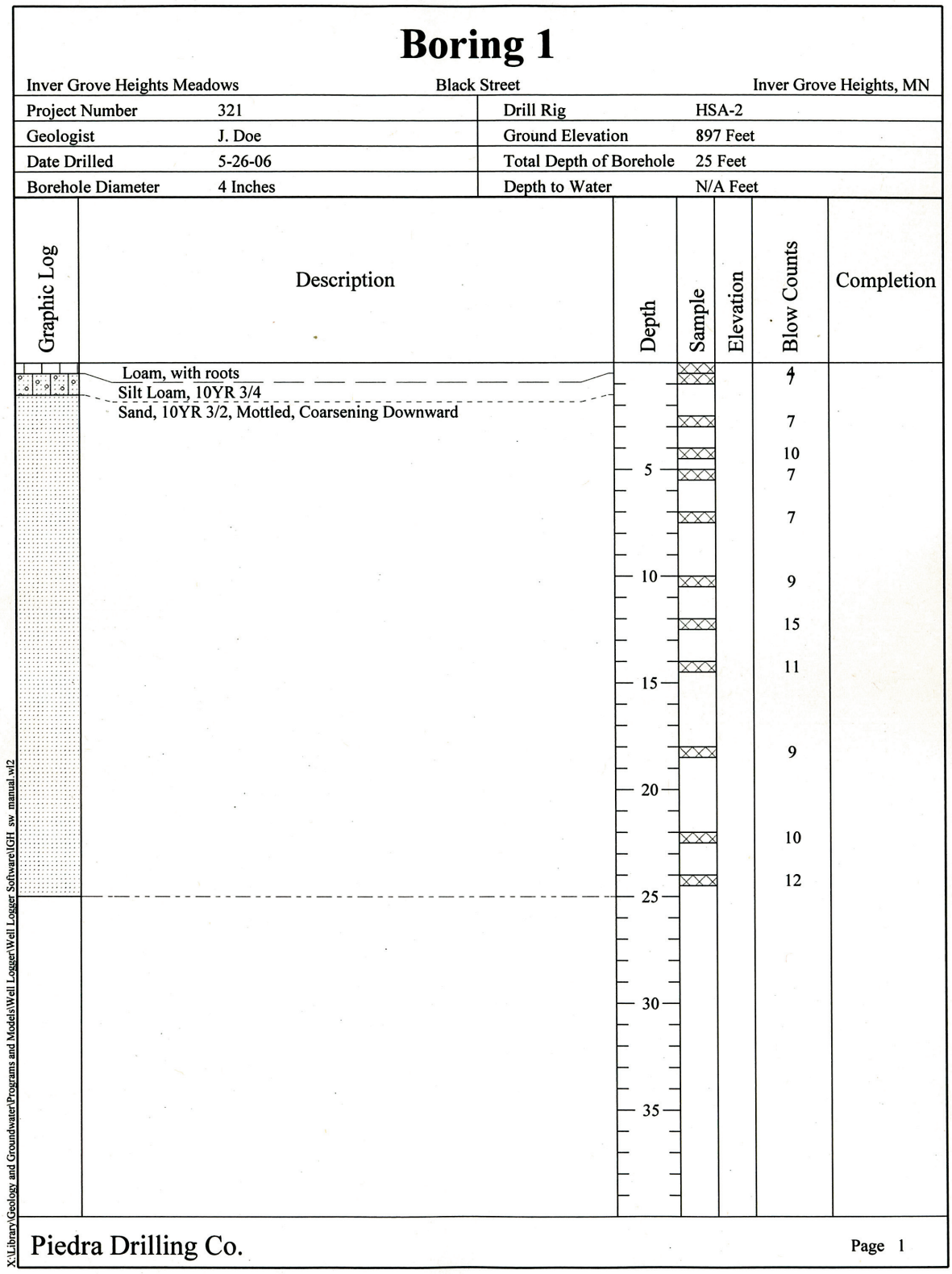


Figure 9.12 Example Calculation Summary for Subwatershed 6-3

Landuse(s): Medium Density Residential
Pretreatment Feature(s): Filter Strips and Vegetated Swales
BMP(s): Biofiltration and Soil Amendments

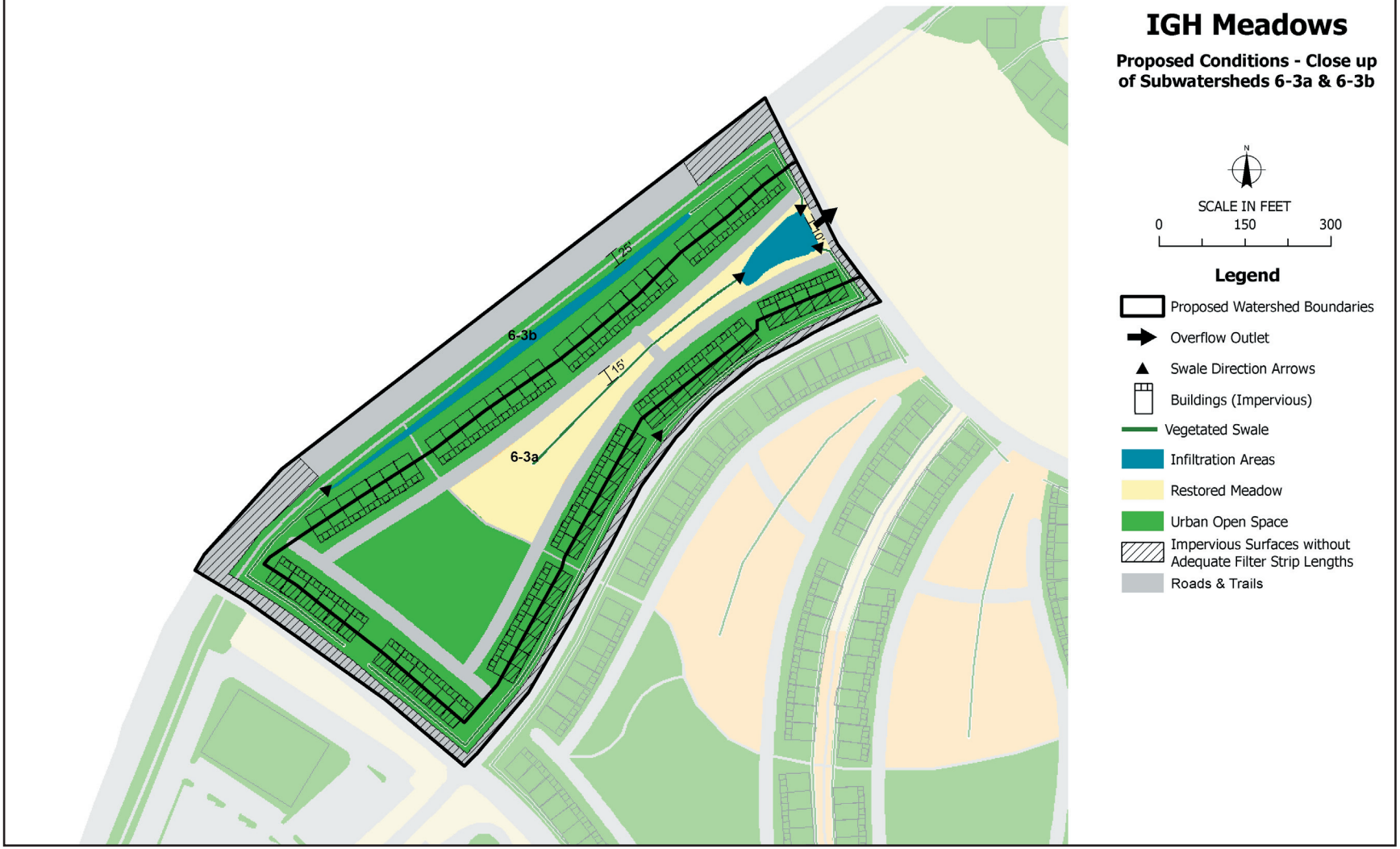


Table 9.16 Subwatershed 6-2	
Step	**Action**
	Compute runoff control volumes as explained in Step 3F. The existing conditions modeled five-year runoff volume into Basin 6 is 1.54 acre-feet with a rate of 1.8 cfs. 1.7 cfs and 1.52 acre-feet of this runoff comes from off-site directly into the basin. Therefore, essentially all of the volume for the surrounding area must be infiltrated before reaching the landlocked basin. This will be accomplished (see Step 6) by sizing the BMP appropriately so that no flow occurs during the 5-year rainfall event for all subwatersheds draining to Basin 6. The runoff control volume for 2.35 acres of land with a composite curve number of 70 is 0.210 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: Depressed Island - For infiltration basins with slopes greater the 3:1 side slopes, use $A_i = V_w/D$ Where: A_i = effective infiltration area at half the volume of the practice* (ft^2) V_w = design volume (e.g. WQ_V) (ft^3) D = maximum depth of practice (feet) For this practice, the V_w is 0.210 acre feet (9,100 ft^3). The maximum depth for the A soil is 3.2 feet (0.8 in/hr x 48 hr*). From the above equation, the A_i is (9,100/3.2) 2,800 ft^2 or 0.07 acres. The actual depressed island has a 0.15-acre footprint, surrounded by a pretreatment buffer. Because the larger footprint was designed (aesthetic reasons), the outlet was moved to two feet above the basin bottom. The results of the 5-year rainfall event from the depressed island into Basin 6, modeled in HydroCAD, can be seen in Table 9.14. The HydroCAD results indicate that the depressed island does not outlet for this rainfall event *It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.
E	**Size outlet structure and/or flow diversion structure, if needed.**
	The depressed island will have an overflow pipe that collects all of the stormwater should the water level increase more than the designed depth of two feet. The overflow pipe will flow into Basin 6 for the large storm events.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.17 Subwatershed 6-3	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	There are two primary drainage conveyance systems in subwatershed 6-3. Both systems are vegetated swales; one located in the center of the subwatershed (6-3a) and one located along the perimeter of the subwatershed (6-3b). Both swales direct water to the downstream BMP. Roads, Driveways, Townhomes - As Figure 9.12 shows, the majority of the impervious surfaces in the subwatershed are smaller than 0.25 acres and provide an adequate **filter strip** distance for pretreatment (see Table 9.12).
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	The hatched areas in Figure 9.12 show the impervious surfaces where an adequately sized filter strip length could not be provided and therefore does not meet the small disconnected impervious drainage system requirements as determined using the flowchart, Figure 9.6. The drainage system that does not meet the filter strip length criteria is a **vegetated swale**, so the pretreatment flowchart indicates that the swale density must be 375 linear feet per acre of impervious surface. The amount of impervious surface requiring pretreatment is 1.99 acres and the length of swale serving this impervious area is 2,600 feet, therefore the pretreatment requirement is satisfied. (375 LF/AC) x (1.99 AC) = 746 LF $\leq$ 2,600 LF
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage systems on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Table 9.17 Subwatershed 6-3

Step	Action
	Subwatershed 6-3 drains into the bioretention basin located southwest of Basin 6. The private roads and back half of the town home roof areas drain into a vegetated swale located in the center of the buffer (subwatershed 6-3a). The public roads and town home front yards drain to a vegetated pretreatment swale which flows into the basin (subwatershed 6-3b). Figure 9.12 indicates the impervious surfaces that are pretreated by filter strips (FS) may be composited.

Subwatershed 6-3a

Soil Type	Land Cover	Acres	CN
-	Impervious	**1.99**	**98**
-	Impervious (FS)	1.66	98
A	Urban Open Space	1.27	39
B	Urban Open Space	0.82	61
		3.75	70

Subwatershed 6-3b

Soil Type	Land Cover	Acres	CN
-	Impervious (FS)	3.76	98
A	Urban Open Space	0.98	39
B	Urban Open Space	0.49	61
A	Meadow	0.55	33
B	Meadow	0.73	45
		6.50	75

D	**Determine the time of concentration for each subwatershed.**
	The T_c was calculated to be 18 minutes for subwatershed 6-3a and 10 minutes for 6-3b.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**

Table 9.17 Subwatershed 6-3

Step	Action
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.13).
C	**Select design variant.**
	The drainage area to the BMP is approximately 12 acres in size. Using the information presented in the following table, a small infiltration basin appears to be the most suitable option for meeting the City's volume control requirements.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**
	Compute runoff control volumes. The total volume running off of subwatershed 6-3 before utilizing bioretention is 1.636 acre-feet. For this subwatershed there are three smaller subwatersheds that need to be modeled.

Subwatershed	Acres	CN	Runoff
6-3a	6.5	75	0.744
6-3b Impervious	1.99	98	0.558
6-3b Composite	3.75	70	0.334

Figure 9.13 Example Soil Boring for Subwatershed 6-3

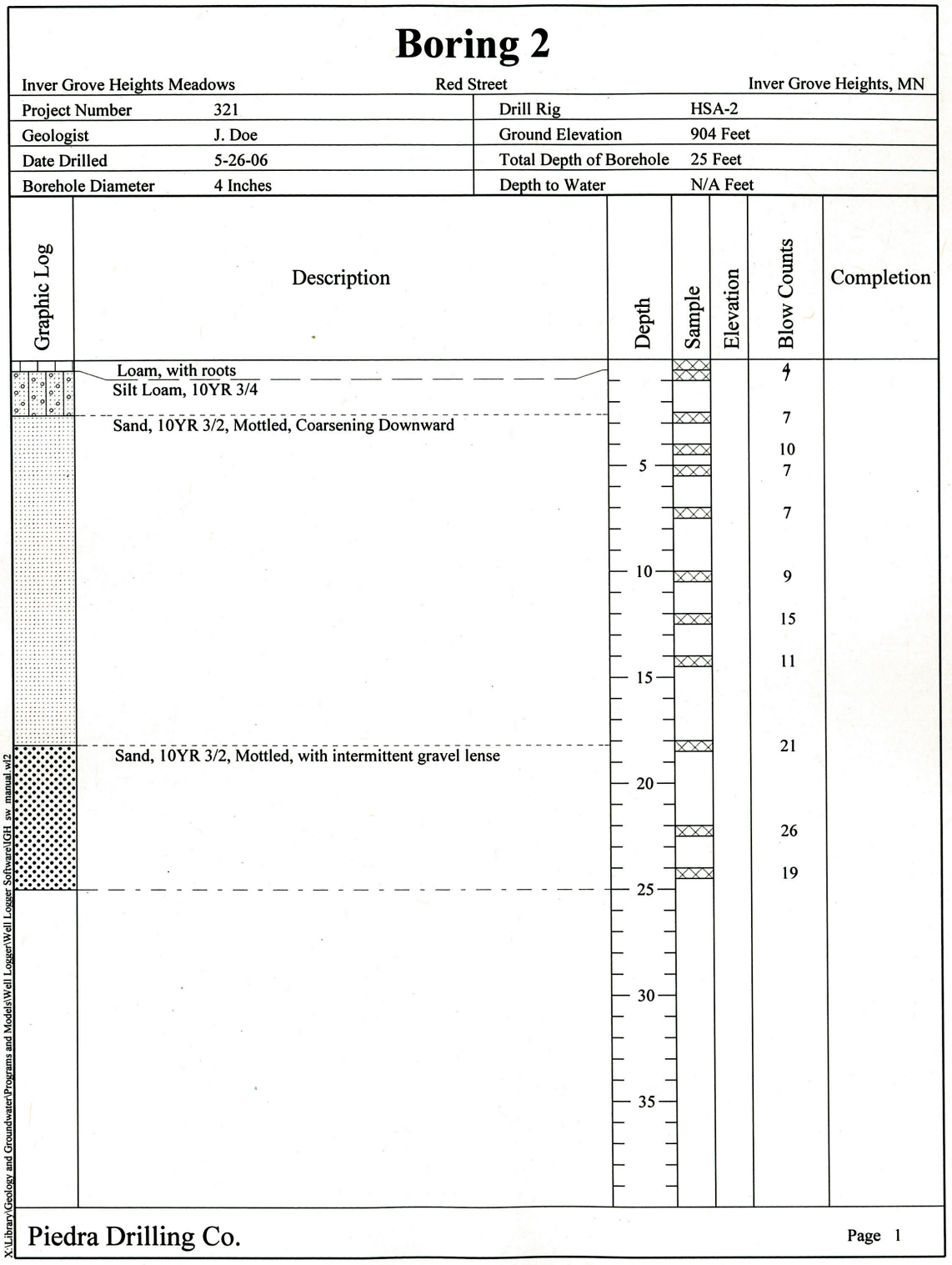


Figure 9.14 Example Calculation Summary for Subwatershed 10-10

Landuse(s): Commercial, High Density Residential, Institutional
Pretreatment Features(s): Filter Strips, Ponds
BMP(s): Bioretention, Parking Lot Islands, Pervious Parking Areas

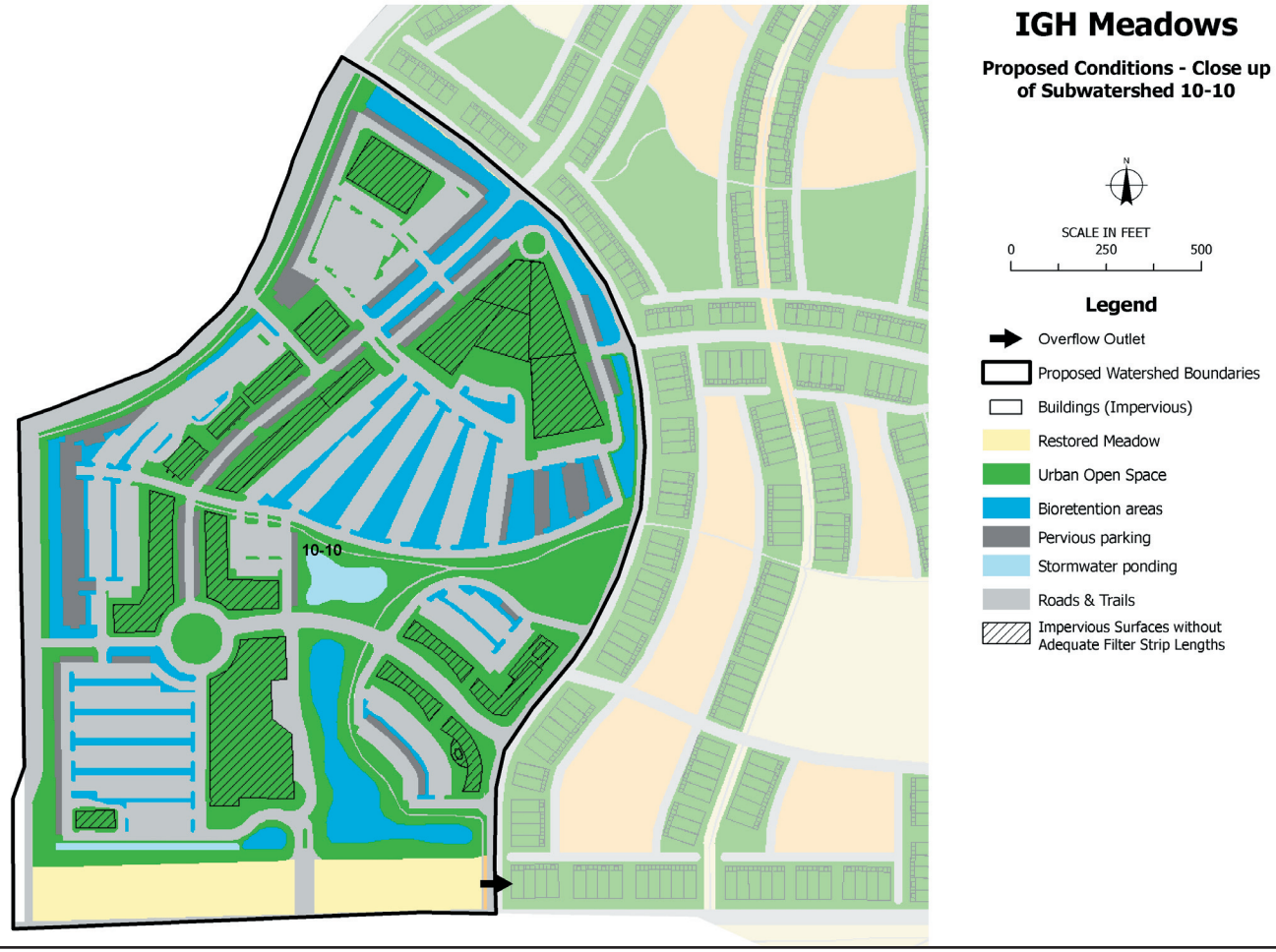


Table 9.17 Subwatershed 6-3	
Step	**Action**
	Because this subwatershed also drains to Basin 6, the bioretention practice must be designed to fully infiltrate the 5-year rainfall event volume. Therefore the water quality volume is 1.636 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: A total of 1.636 acre-feet of runoff volume reaches the bioretention areas. Both bioretention areas are located in soil type 454C, an A type soil. An infiltration rate of 0.8 in/hr is used for design. The maximum depth possible is 3.2 feet (48 hr* x 0.8in/hr), so the required surface area was calculated to be 0.51 acres (1.636 acre-feet / 3.2 feet). The required area of bioretention provided by the roadside and central raingardens. (Note: It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.)
E	**Size outlet structure and/or flow diversion structure, if needed.**
	The small infiltration basin has a 24" RCP overflow culvert located two feet above the basin bottom. It drains north under the road and into Basin 6. The outlet is sized so that the road will not come within two feet of overtopping during the 100-year event.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.18 Subwatershed 10-10	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	It is more difficult to show that the pretreatment has been satisfied for the high-density development areas. The higher percentage of impervious surfaces means longer flow routes and more concentrated flow. Pervious Parking Areas - No pretreatment is possible for the pervious parking areas because no routing of runoff occurs, the stormwater directly enters the underground storage. The "pretreatment" for this system will occur by the **sweeping or vacuuming** that is part of the operation and maintenance plan. If the pervious pavement was designed to receive runoff from the impervious parking areas, pretreatment would be required for the pervious parking. Traditional Parking Areas - Because of the large number of parking stalls required for this area (>100), the PUD requires landscaped islands be used between double loaded rows of parking. The **landscaped islands** were designed to meet the 0.25 acre drainage area minimum. This was done by limiting the drainage area to each curb cut inlet. The flow length into most of the islands is longer than 35 feet, requiring a filter strip length of 20 feet (1% slope). In many cases the islands will not be more than 20 feet wide. Therefore the filter strip will begin at the curb cut inlet and continue to the infiltration area. It is imperative that the filter strip length does not overlap with the infiltration area. The practice may not bounce to the elevation of the filter strip for the 3.6", 24-hour rainfall event or smaller. The infiltration islands were designed to meet this criterion.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	Bioretention Areas/Infiltration Basins - There are many larger centralized bioretention areas located throughout the site. These can be seen in Figure 9.14. These areas collect runoff from the immediately adjacent area. The drainage area for each two of these bioretention features (located south and southeast of the big box store) is greater than 0.25 acres and is not vegetated; meaning another type of pretreatment is required. The drainage area for these bioretention areas is 30 acres, including 20 acres of impervious surfaces. Both of these features are pretreated using ponds. Ponds for this area (Type III Drainage System) require 1,800 ft^3 of dead storage per acre of impervious drainage area. The mean normal depth for each pond was constructed to be four feet deep. Therefore the total pond surface area is: [(20 impervious acres) x (1,800 ft^3 / acre) / (4 feet)] = 9,000 ft^2. Both ponds were placed just upstream of the large bioretention areas and satisfy the pretreatment requirements.
3	**Develop post-development surface water model.**

Table 9.18 Subwatershed 10-10	
Step	**Action**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Subwatershed 10-10 is composed of commercial, institutional, and high-density residential (elderly living) land use. After delineating the subwatershed boundaries, the parking requirements were calculated according to City Ordinance 558 and the PUD. The following tables summarize the analysis

City of Inver Grove Heights Parking Requirements (City Ordinance 558)					
Land Use	**Specific Use**	**Area [ac]**	**Area [sq. ft.]**	**Maximum Parking Stalls**	**Minimum Parking Stalls**
Commercial Buildings	**Retail Stores**	4.551	198,242	**1,322**	**991**
	Auto Repair	0.235	10,237	**21**	**16**
Institutional Buildings	**Church**	2,187	1,900	**543**	**407**
Residential Buildings	**Single Family**	No parking beyond that provided by the garage is required			
	Medium Density	100	342	**171**	**128**
	Elderly Apartments	10	300	**450**	**338**
NOTE: Only the elderly apartments contain more than 100 spaces together and thus require pervious pavement.					

TOTAL STALLS:	**2335**	**1751**
	MAX	**MIN**

TOTAL PARKING STALLS CONSTRUCTED:	**2276**	**Parking Stalls**
PERVIOUS PAVEMENT REQUIRED FOR:	**525**	**Parking Stalls**

Table 9.18 Subwatershed 10-10

Step	Action

Pervious Parking Area Requirement Calculation

Parking Area Supplied:	15,236	acres
Parking Stalls Designed:	2276	Parking Stalls
Parking per Stall:	292	sq. ft.
Impervious Parking Stalls:	1751	
Pervious Parking Stalls:	525	
Impervious Parking Area:	11.7	acres
Required Pervious Parking Area:	3.5	acres

This development has 2,276 parking stalls. The maximum number permitted under City Ordinance 558 is 2,335, and the minimum is 1,751. Shared parking was used on the site to minimize the number of parking stalls constructed. The number of pervious parking stalls required for the site is the difference between the minimum stalls and the constructed stalls. For this area, the number of parking stall required is 525 (2276-1751). The total parking area allotted is 15.2 acres, which indicates that one parking stall requires an average paved surface area of 292 ft^2 for this development. Therefore the amount of pervious pavement needed is 3.5 acres [(525 stalls x 292 ft^2/stall)/43,560 ft^2/acre]. This pervious pavement requirement is allocated in the overflow parking areas. All of the pervious pavement area is assigned a curve number of 100 and is modeled as an underground dry pond (more details in BMP design section). The curve number calculation (divided into the three subwatersheds) is shown below.

Soil Type	Land Cover	Acres	CN
-	Pervious Parking	**3.5**	**100**
-	Impervious including ponds	**12.10**	**98**
-	Impervious (FS)	20.00	98
A	Meadow	1.14	33
A-B	Meadow	5.31	35
B	Meadow	5.53	45
A	Graded Urban Open Space	2.55	50
A-B	Graded Urban Open Space	6.88	61
B	Graded Urban Open Space	3.52	74
		44.93	**72**

D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 15 minutes for these subwatersheds.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15

Table 9.18 Subwatershed 10-10

Step	Action
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.15).
C	**Select design variant.**
	The drainage area to the BMP is approximately 1 acre in size. Using the information presented in the following table, the depressed island (bioretention) appears to be the most suitable option for the stormwater management practice.

BMP Design Variant	Drainage Area (Acres)
Bioretention	0.5 - 2
Infiltration	
Infiltration Basin	5 - 50
Infiltration Trench	< 5
Dry Wells	< 1
Underground Infiltration Systems	< 10
Green Roofs	
Pervious Surfaces	
Rainwater Harvesting	
Stormwater Ponds	> 25
Stormwater Wetlands	> 25

D	**Size BMP.**

Table 9.18 Subwatershed 10-10	
Step	**Action**
	Compute runoff control volumes. Pervious Pavement – The pervious pavement was designed with an effective storage depth of two feet and a void ratio of 0.30. This 3.5-acre area is given a curve number of 100 and routed to a two-foot deep, 3.5-acre dry pond with 30% voids. The pond does not outlet for the 5-year event. Parking Lot Islands – The parking lot islands are a required better site design technique and were applied throughout the commercial parking lot area. They were designed with filter strips as pretreatment and to store and infiltrate at least the first 0.5 inches of runoff from the surrounding impervious surfaces. The islands were located on all three soil types and modeled appropriately for the surrounding soil type. The total runoff volume into the parking lot islands is 4.4 acre-feet coming from 44.3 acres with a CN of 72. Infiltration Basin – While the pervious pavement and parking lot islands were mandated by city ordinances, the large infiltration basin is added in order to meet site runoff volume control requirements. After modeling the pervious pavement and parking lot islands, 4.42 acre-feet of runoff was entering the infiltration basin. The volume entering Basin 10 according to the existing conditions model was 3.32 acre-feet, with 1.80 acre-feet coming from two off-site subwatersheds and 0.14 acre-feet from Basin 10 itself. Therefore the maximum volume allowed to Basin 10 from all of the developable area draining to Basin 10 is (3.32-1.80-0.14) 1.38 acre-feet. The commercial area is the most densely developed and inherently difficult to meet the volume standards. Therefore the development was designed so that the allowable 1.38 acre-feet of volume will be allowed to enter the basin from subwatershed 10-9. More stringent requirements allowing no runoff from the five-year event will be applied to all other basins draining to Basin 9. Before the infiltration basin is accounted for, the runoff volume is 4.42 acre-feet. The design water quality volume is then (4.42-1.38) 3.04 acre-feet. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: Pervious Pavement – Designed per manufacturer's specifications. In this case it has an effective depth of 3.5 feet and a void ratio of 0.30. Parking lot islands – The parking lot islands were designed to have a depth of one foot before the drop structure became an effective outlet. They were planted with native species and sized to accommodate most of the 5-yr rainfall event. Infiltration Basin - For infiltration basins with slopes greater the 3:1 side slopes, use $A_i = V_w/D$ Where: A_i = effective infiltration area at half the volume of the practice* (ft^2) V_w = design volume (e.g. WQ_V) (ft^3) D = maximum depth of practice (feet) For this practice, the V_w is 3.04 acre feet (132,400 ft^3). The maximum depth for the AB soils is 2.4 feet (48 hr* x 0.5 in/hr). From the above equation, the A_i is (132,400/2.4) 55,000 ft^2 or 1.26 acres. *It is assumed for these calculations that the facility is being designed to meet the more stringent MPCA requirements for a drawdown within 48 hours instead of the IGH standard of 72 hours.
E	**Size outlet structure and/or flow diversion structure, if needed.**

Figure 9.15 Example Soil Boring for Subwatershed 10-10

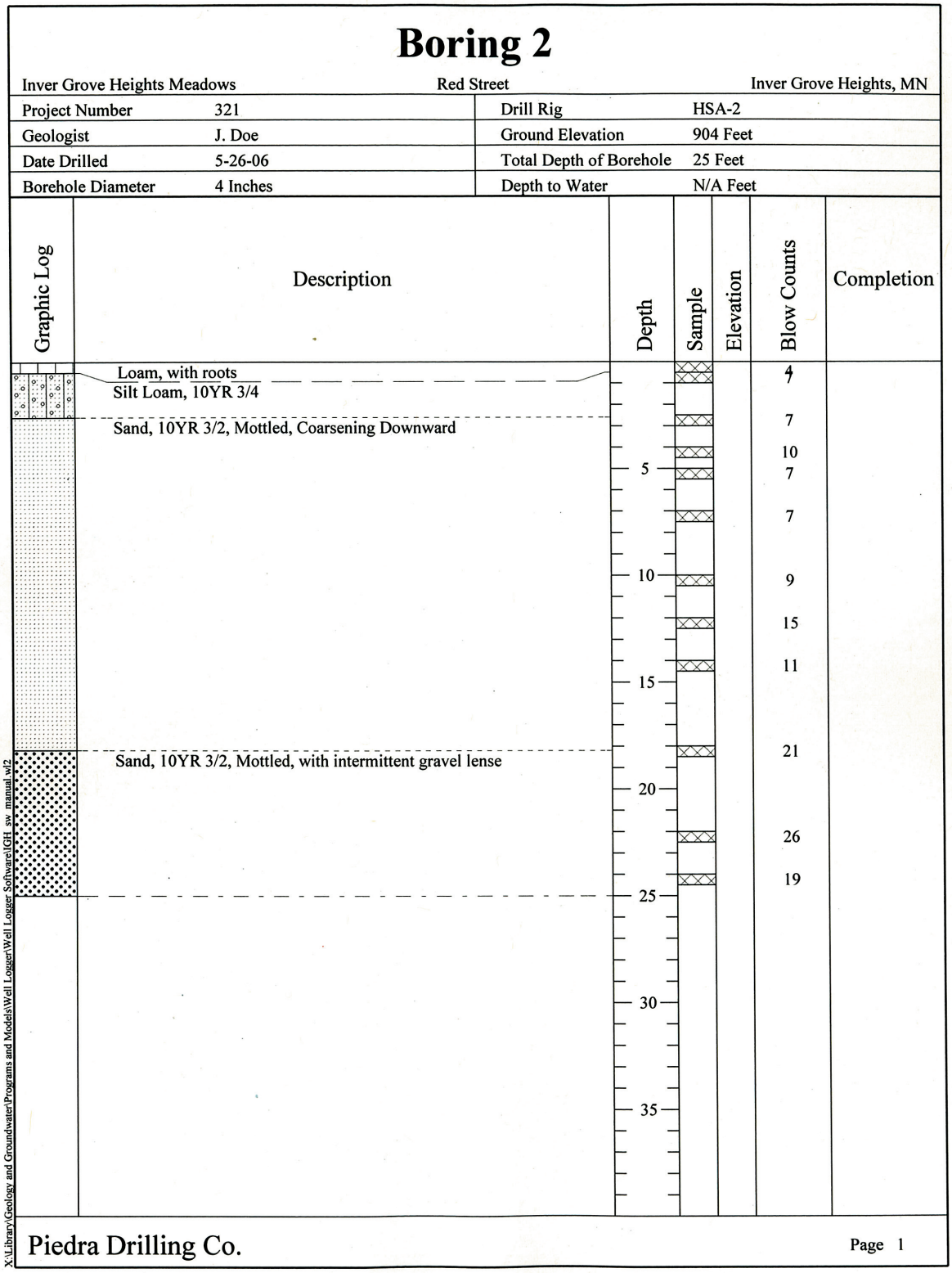


Figure 9.16 Example Calculation Summary for Subwatershed 11-1

Landuse(s): Natural Open Space and Manage 1 Wetland
Pretreatment Feature(s): None
BMP(s): None

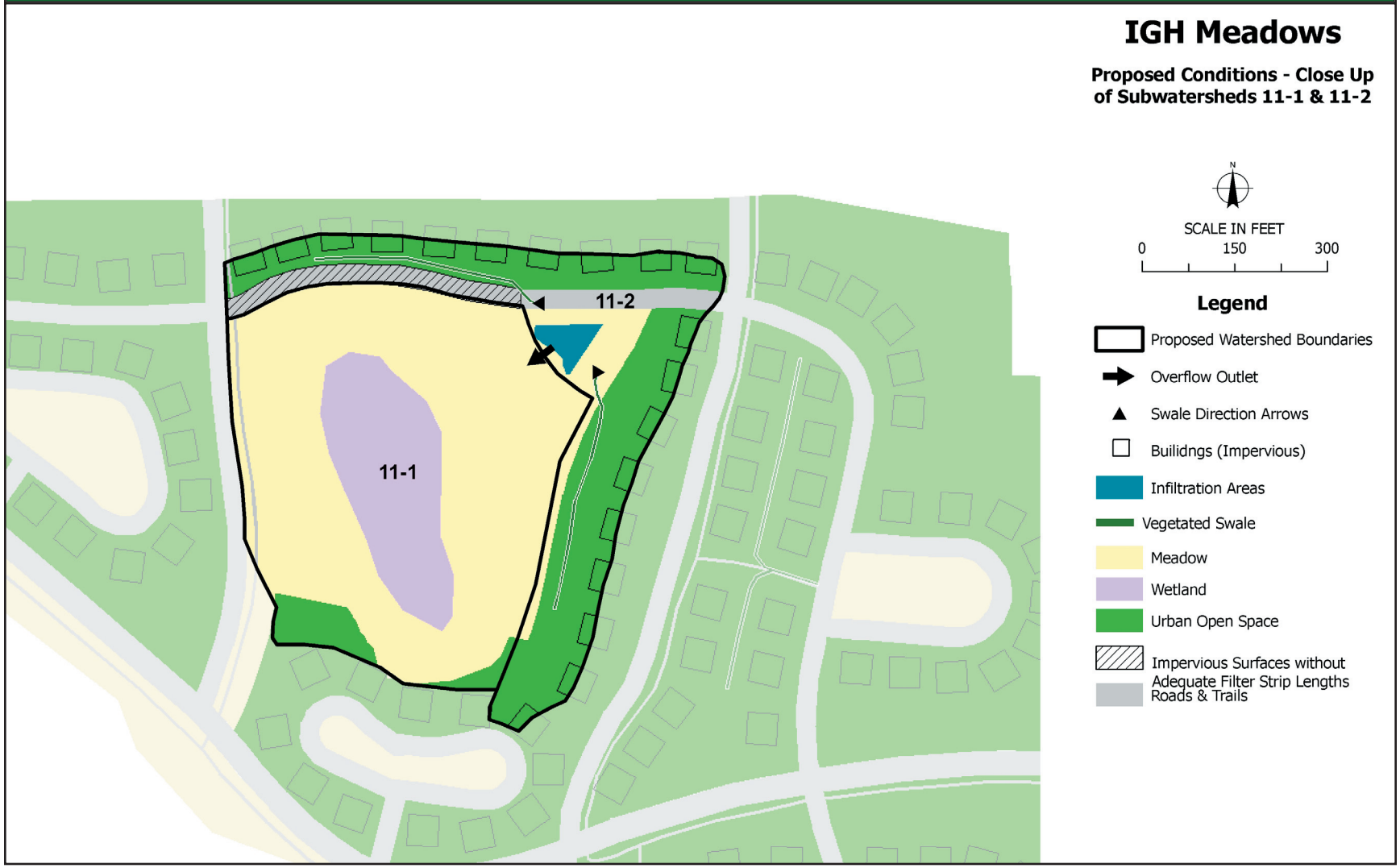


Table 9.18 Subwatershed 10-10	
Step	**Action**
	Pervious pavement: - The primary outlets are the appropriate number of drain tile outlets (varies by location) located two feet above the pond bottom. An emergency overflow is also utilized that allows the pavement to drain to the surrounding traditional pavement and into the parking lot islands. Parking lot islands – The outlet for the parking lot islands are drop structure outlets that connect to a small stormsewer system that drains into the large bioretention area. Infiltration basin – The primary outlet consists of a drop structure draining into a 1,500-foot long, 24-inch RC pipe outletting to Basin 9. It also has an emergency overflow that outlets into a roadside swale adjacent to the road, ultimately reaching Basin 9. The emergency overflow will only be utilized for rainfall events greater than the 100-year event.
F	**Perform groundwater mounding analysis.**
	The groundwater mounding analysis was not performed for the example site, but will be required for approval.
5	**Summarize the results of the post-development analysis**
	See Table 9.15

Table 9.19 Subwatershed 11-1	
Step	**Action**
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	There is no pretreatment requirement because there are no BMPs or impervious surfaces in the subwatershed except for a trail made of pervious pavement. No small disconnected impervious areas on site
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	No large disconnected impervious areas on site
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage areas on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**

Figure 9.17 Example Soil Boring for Subwatershed 11-1

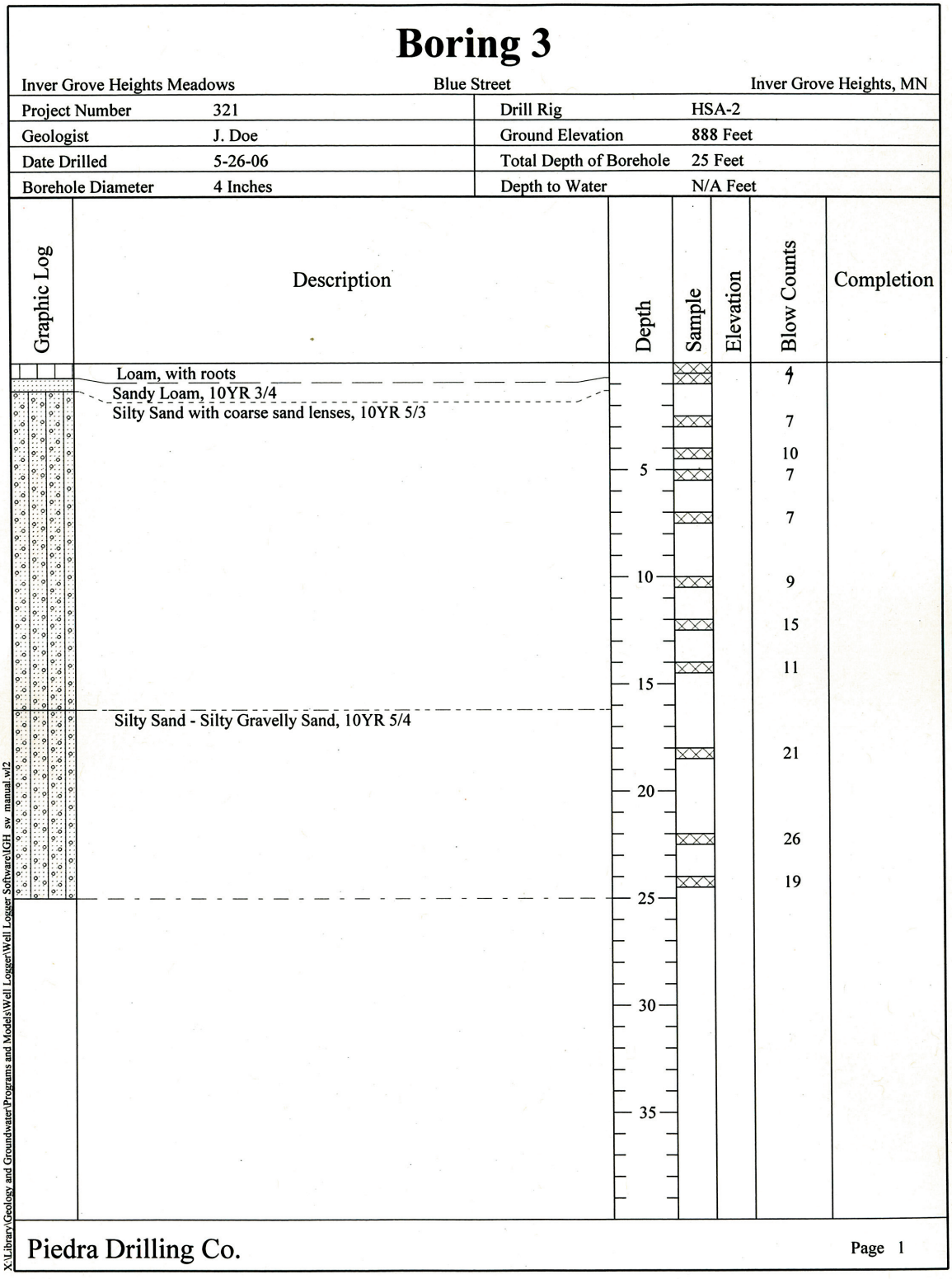


Figure 9.18 Example Calculation Summary for Subwatershed 11-2

Landuse: Low Density Residential
Pretreatment Feature(s): Filter Strips and Vegetated Swales
BMP(s): Infiltration Trench and Soil Amendment

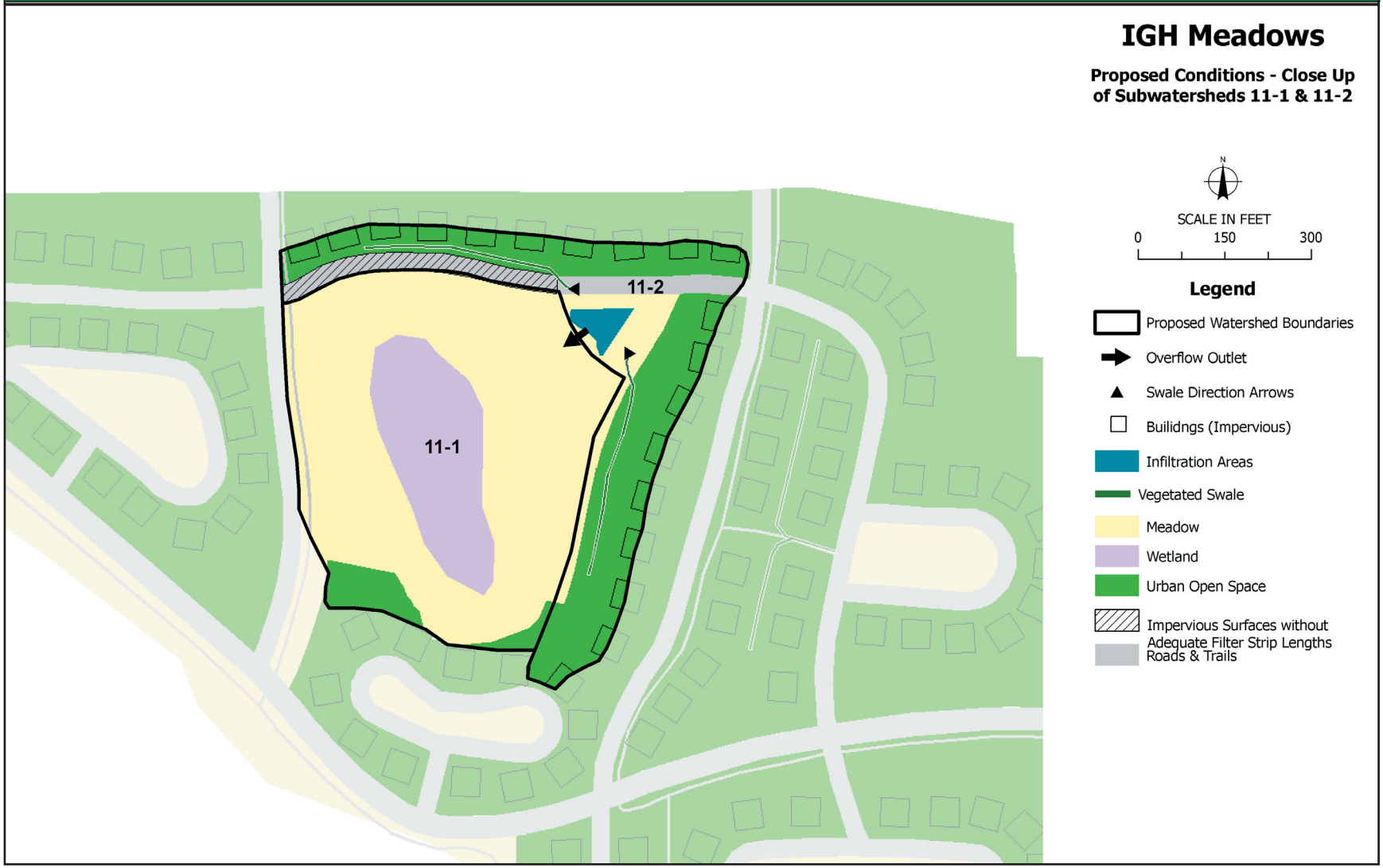


Table 9.19 Subwatershed 11-1

Step	Action
	Subwatershed 11-1 contains a Manage 1 wetland. The stormwater requirements for a Manage 1 wetland are more intense than for other features (no increase in HWL for 100-year event). There are no BMPs included in this area, instead it remains in its original, undisturbed natural state, meaning the volume cannot increase. The subwatershed boundaries were originally delineated to include the rear yards of some of the adjacent homes. However, the 5-year runoff volume increased from existing to proposed conditions. Then the drainage boundary was re-graded so that only the wetland and basin drainage were allowed to drain to the wetland. However, the high wetland curve number had such a strong effect on the subwatershed composite curve number that the runoff volume still increased using SCS methodology. This type of effect is rare, but can occur when there is a large separation in curve numbers. In this rare circumstance, the curve numbers should not be composited. This error is inherent with the use of curve numbers. Subwatershed 11-1 in proposed conditions and subwatershed 15 in existing conditions were modeled discretely without compositing the curve numbers. This methodology better reflected what was actually occurring in the drainage region and showed a decrease in runoff volume.

Soil Type	Land Cover	Acres	CN
B	Meadow	5.37	45
A-B	Urban Open Space	0.002	50
B	Urban Open Space	0.57	61
B	Wetland	1.39	78
		7.34	**53**
NOTE: Composite CN of 53 was not used in the calculation.			

D	**Determine the time of concentration for each subwatershed.**
	The time of concentration was calculated to be 30 minutes for this subwatershed.
E	**Calculate peak flow rates for applicable rainfall events.**
	See Table 9.15
4	**Design stormwater BMPs**
A	**Is site appropriate for BMPs and where will it function in the treatment train?**
	Yes, the site meets the criteria outlined in Step 4.A. Stormwater runoff receives pretreatment as described in Step 2 prior to flow to the BMP. The BMP will serve as the downstream feature in a landlocked system where the natural overflow is being preserved (Category 1).
B	**Perform field verification.**
	The soil borings performed on-site indicate that the soils are suitable for the design and construction of an infiltration practice. A soil boring representative of the soils found in the location of the proposed BMP indicates that the infiltration rates assumed in the stormwater calculations are appropriate (see Figure 9.17).
C	**Select design variant.**
	No BMP required as the natural drainage area was decreased for wetland protection purposes.

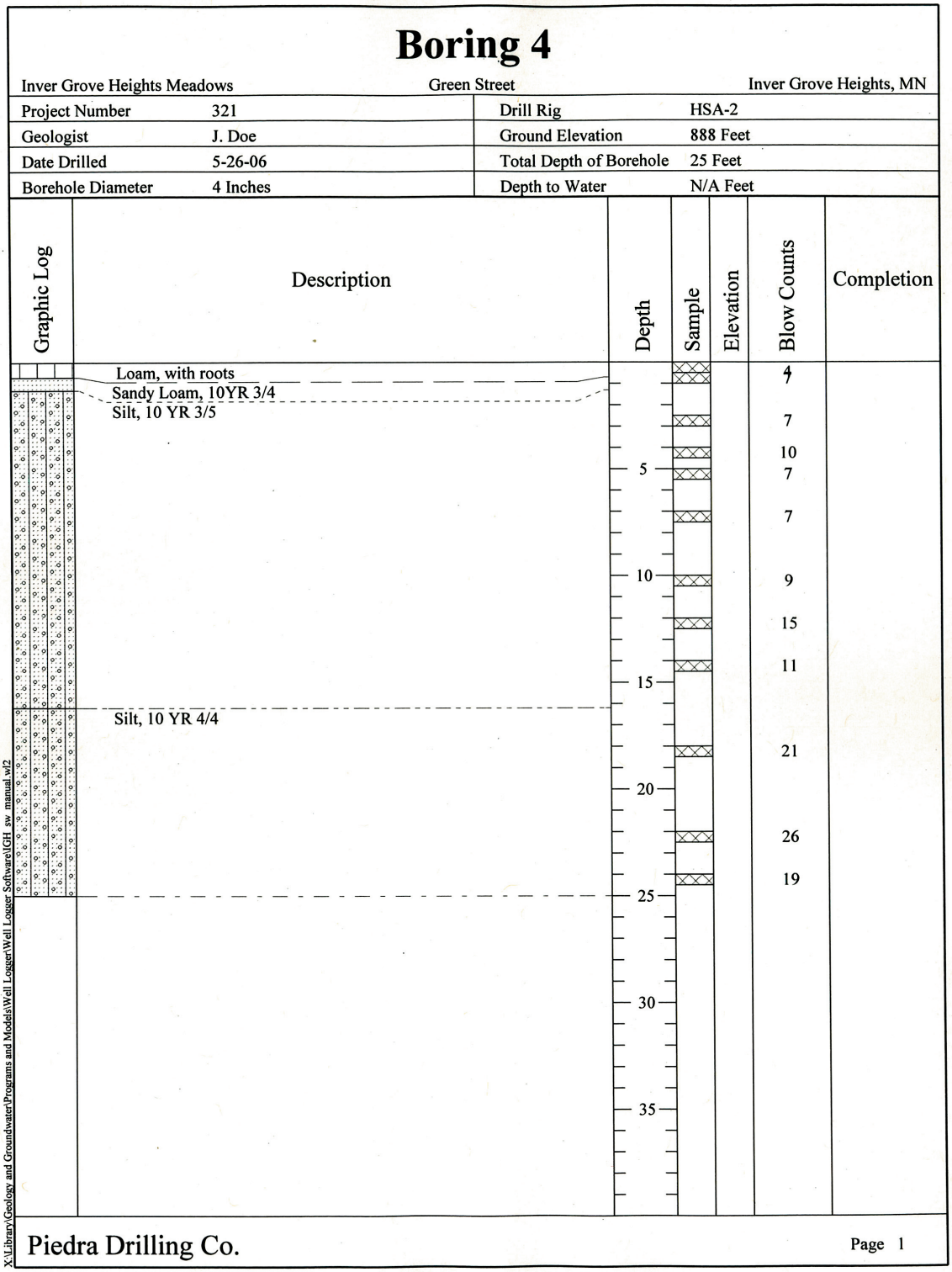
Table 9.19 Subwatershed 11-1	
Step	**Action**
D	**Size BMP.**
	Compute runoff control volumes. Because the subwatershed has a smaller area from existing to proposed conditions and all of the area is remaining undisturbed, the runoff volume decreases without requiring any control volume. To size the BMP perform the following steps as identified in Chapter 8 of this Manual: No BMPs are used.
E	**Size outlet structure and/or flow diversion structure, if needed.**
	See Step 6.
F	**Perform groundwater mounding analysis.**
	Not required since no BMPs designed for this subwatershed.
5	**Summarize the results of the post-development analysis**
	See Table 9.15 Because the subwatershed has a smaller area from existing to proposed conditions and all of the area is remaining undisturbed, the wetland will meet the Manage 1 HWL requirement.

Table 9.20 Subwatershed 11-2

Step	Action
1	**Determine subwatershed boundaries and develop post-development conditions drainage map.**
	See Figure 9.8
2	**Determine pretreatment requirements and design pretreatment measures.**
A	**Identify on the site plan all impervious areas that flow over an approved filter strip.**
	Subwatershed 11-2 contains an infiltration trench for a BMP. A total of 1.06 acres of impervious surfaces exist in the subwatershed. 0.70 acres of impervious surfaces are pretreated by filter strips.
B	**Identify all areas that are part of a large disconnected impervious drainage system**
	0.36 acres of impervious are pretreated by two **vegetated swales**. These swales have a total length of 800 feet, thus providing adequate pretreatment for the impervious surfaces. (375 LF/AC) x (0.36 AC) = 135 LF ≤ 800
C	**Design Filter, Pond, or Proprietary device to remove 85% TSS for impervious drainage areas not identified in steps A and B.**
	No centralized drainage areas on site
3	**Develop post-development surface water model.**
A	**Identify the soils on site.**
	See Figure 9.7
B	**Determine type of land cover on site.**
	See Figure 9.8
C	**Assign curve numbers based on Table 9.5 and calculate composite curve numbers for each subwatershed.**
	Subwatershed 11-2 is a 3.8-acre subwatershed draining into a Manage 1 wetland. The runoff is directed through a small vegetated swale and into an infiltration trench. Because all of the pretreatment requirements for this subwatershed are met by filter strips, the CNs were composited.

Soil Type	Land Cover	Acres	CN
-	Impervious	0.36	98
-	Impervious (FS)	0.70	98
B	Meadow	0.19	45
B	Urban Open Space	1.88	61
		7.34	**53**

Figure 9.19 Example Soil Boring for Subwatershed 11-2



VIII. References

Inver Grove Heights Comprehensive Plan. 2006. Inver Grove Heights, MN.

Inver Grove Heights Northwest Area Natural Resource Inventory and Management Plan. 2003. Bonestroo, Rosene, Anderlik and Associates, Inver Grove Heights, MN.

The Minnesota Stormwater Manual. 2006. Minnesota Pollution Control Agency, St. Paul, MN.

Site Evaluation for Stormwater Infiltration. 2004. Wisconsin Department of Natural Resources Conservation Practice Standards 2004

Technical Memorandum to the Inver Grove Heights Low Impact Development (LID) Stormwater Plan: Overflow Contingencies and Cost Analysis. 2006. Emmons and Olivier Resources, Inc., Oakdale, MN.

INVER GROVE HEIGHTS
Northwest Area

Appendix A

CADD Details

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

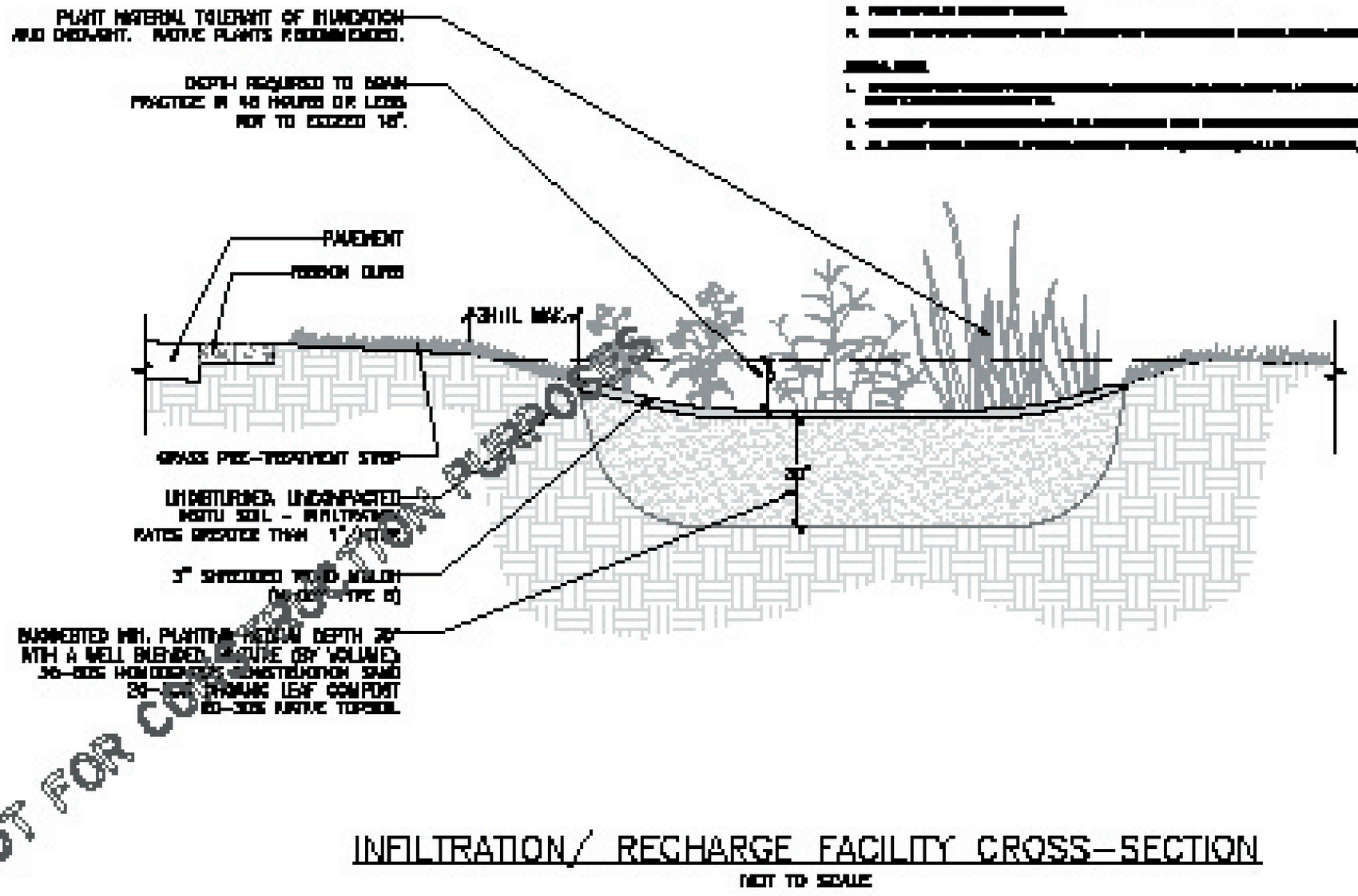
CADD Details

Appendix A

Contents

I. Infiltration/Recharge Facility Cross-Section..... 3
II. Bioretention Facilities General Plan..... 4
III. Filtration/Partial Recharge Facilty Cross-Section..... 5
IV. Infiltration/Filtration/Recharge Facility Cross-Section..... 6
V. Filtration Only Facility Cross-Section..... 7
VI. Typical Dry Swale Cross-Section..... 8
VII. Perimeter Sand Filter Details..... 9
VIII. Surface and Filter Detail..... 10
IX. Underground Sand Filter..... 11
X. Typical Infiltration Trench Cross-Section..... 12
XI. Infiltration Plans and Profile..... 13
XII. Infiltration Subsurface Plans and Profile..... 14
XIII. Typical Pond Plan and Profile..... 15
XIV. Extended Detention Shallow Wetland Plan and Profile..... 16
XV. Multi-Stage Outlet Structure (Orifice example)..... 17
XVI. Shallow Wetland Plan and Profile..... 18

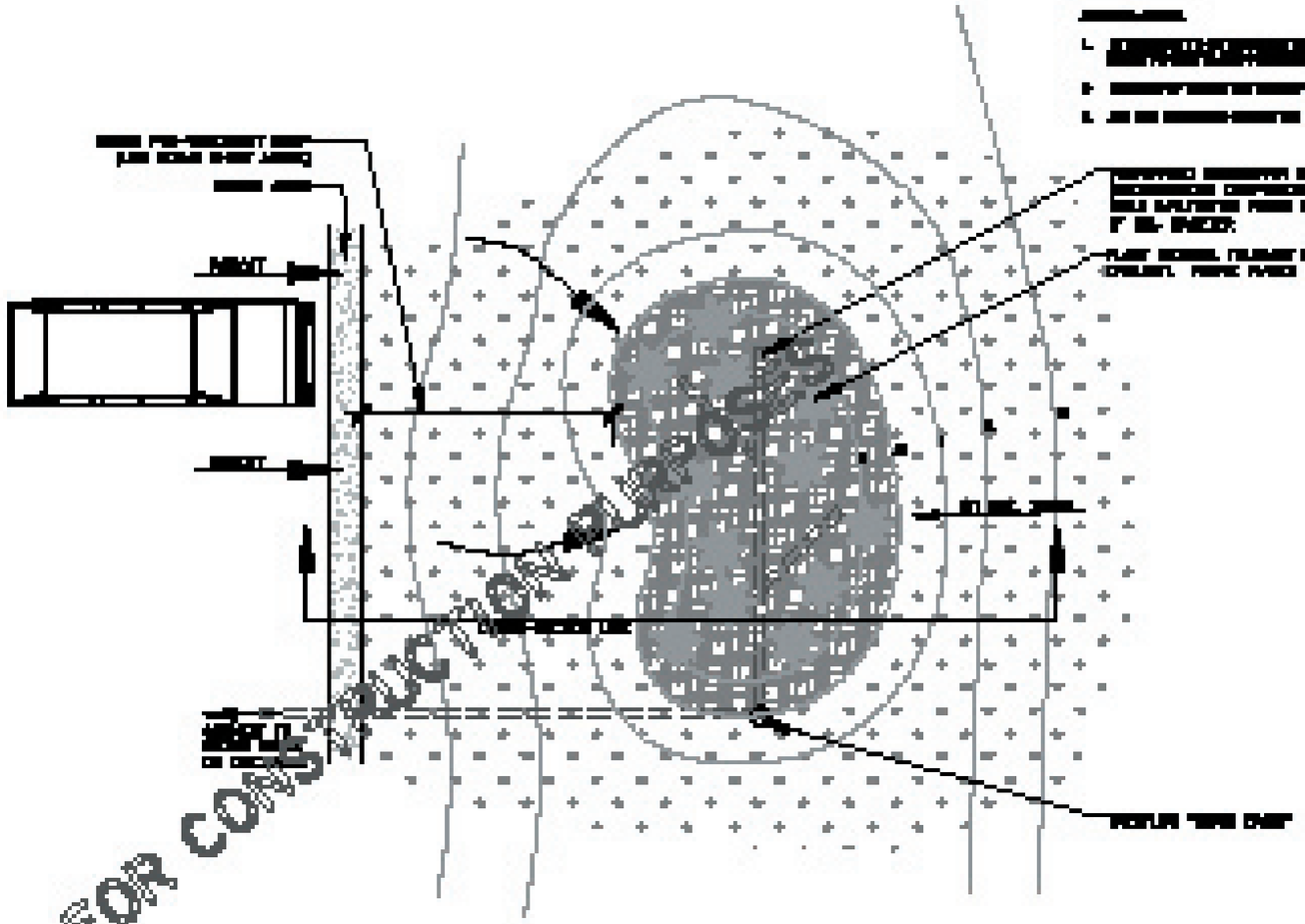
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NOT FOR CONSTRUCTION

INFILTRATION/ RECHARGE FACILITY CROSS-SECTION

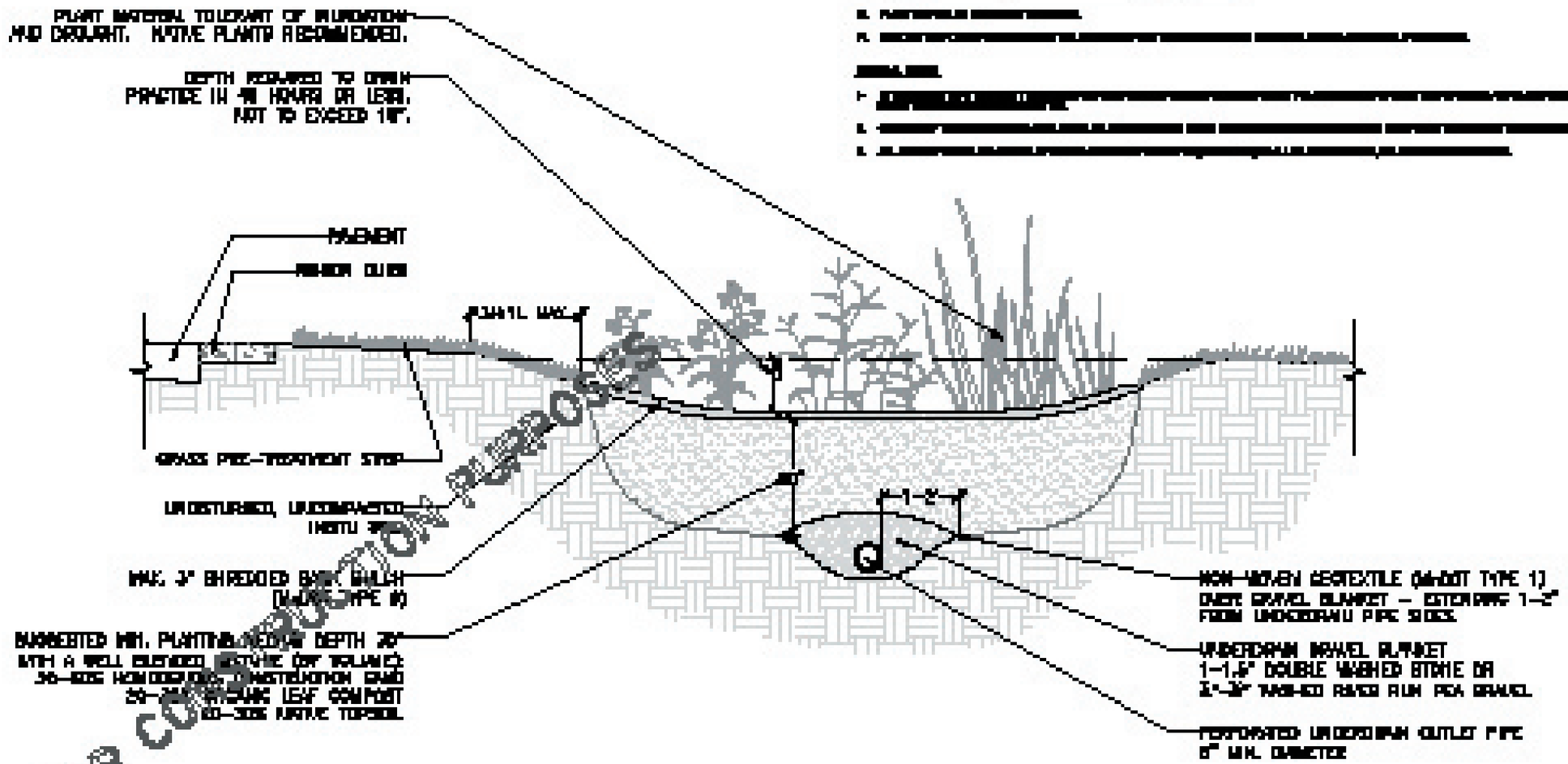
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BIORETENTION FACILITIES GENERAL PLAN

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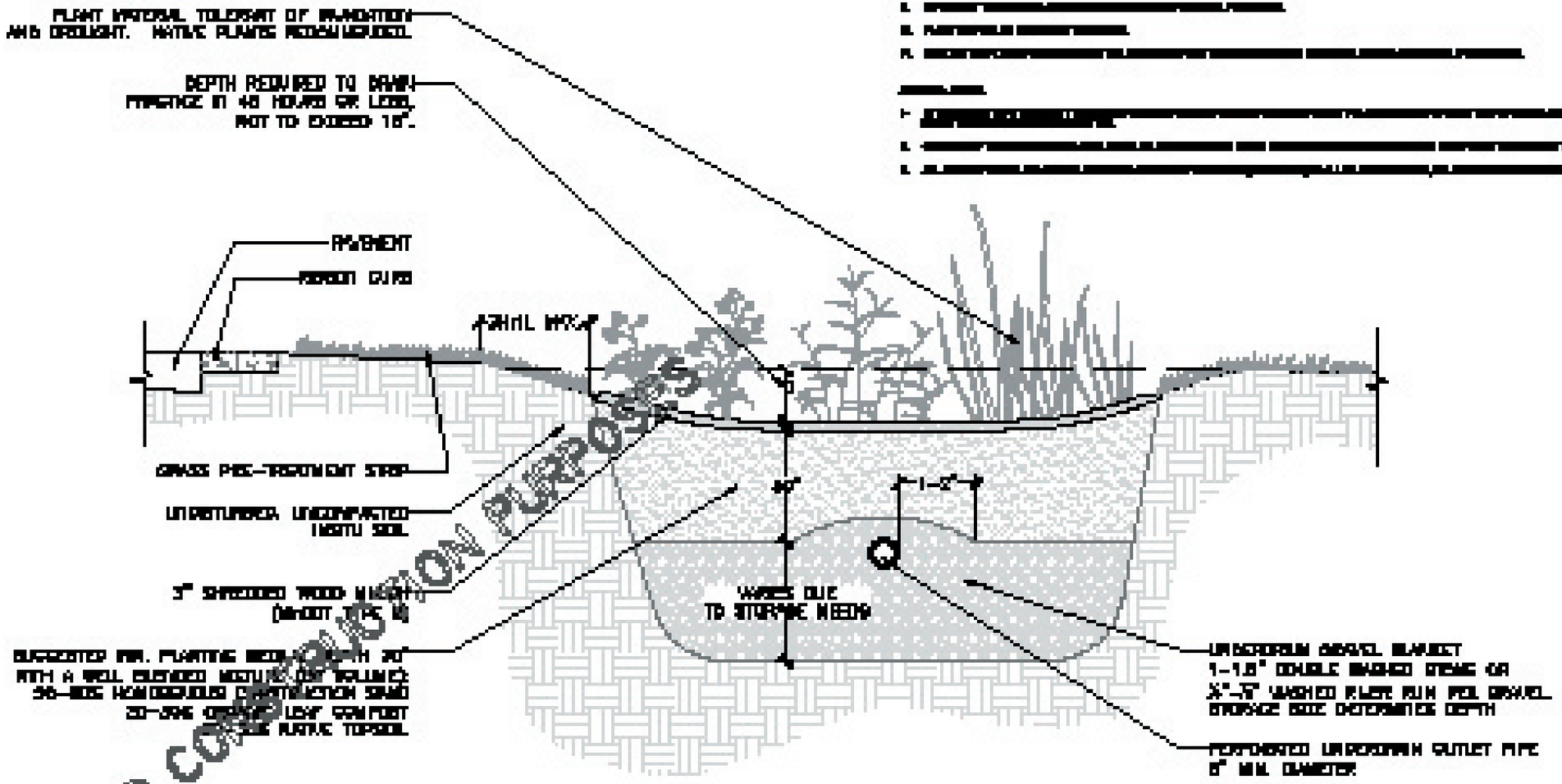


NOT FOR CONSTRUCTION PURPOSES

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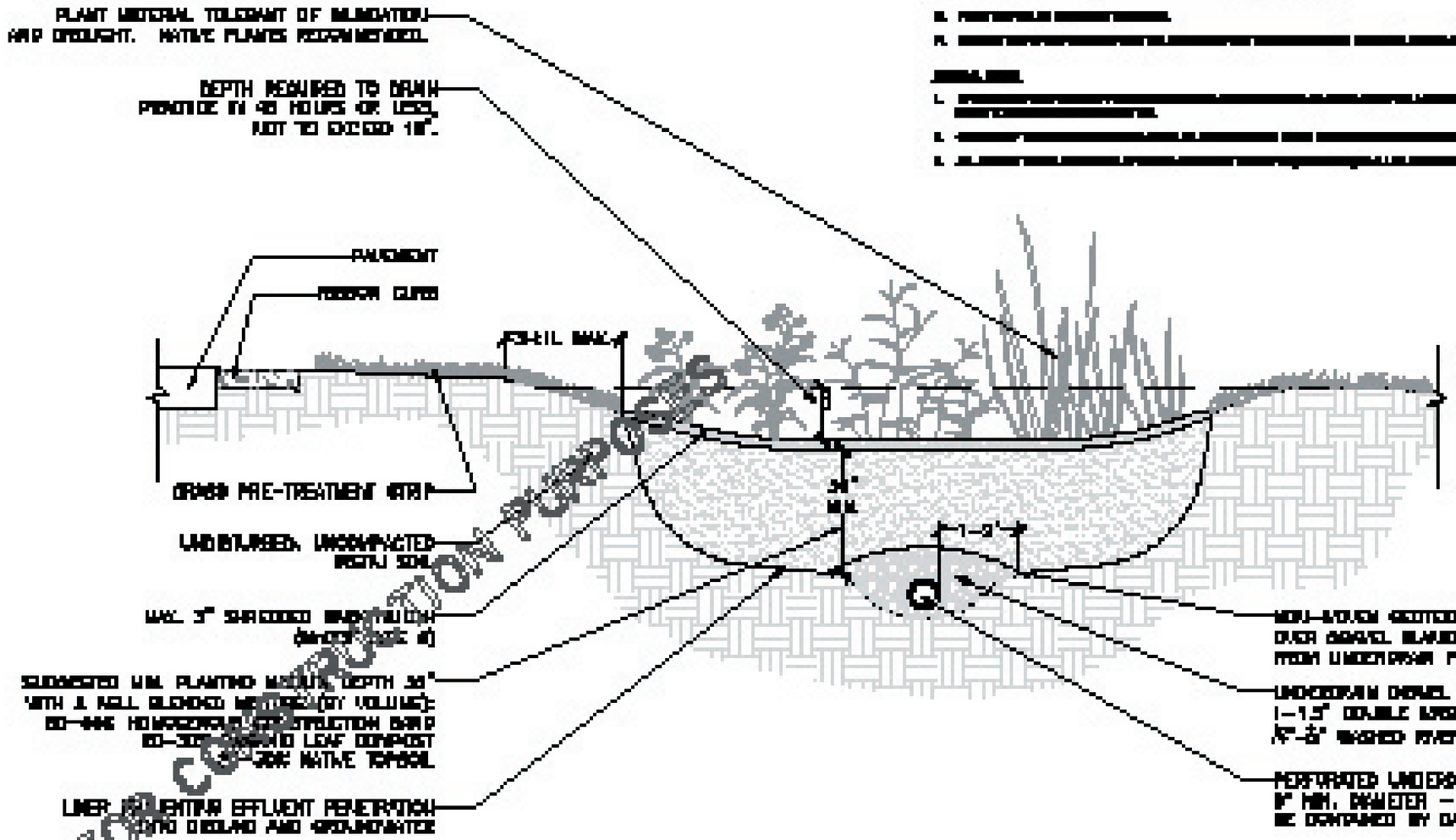


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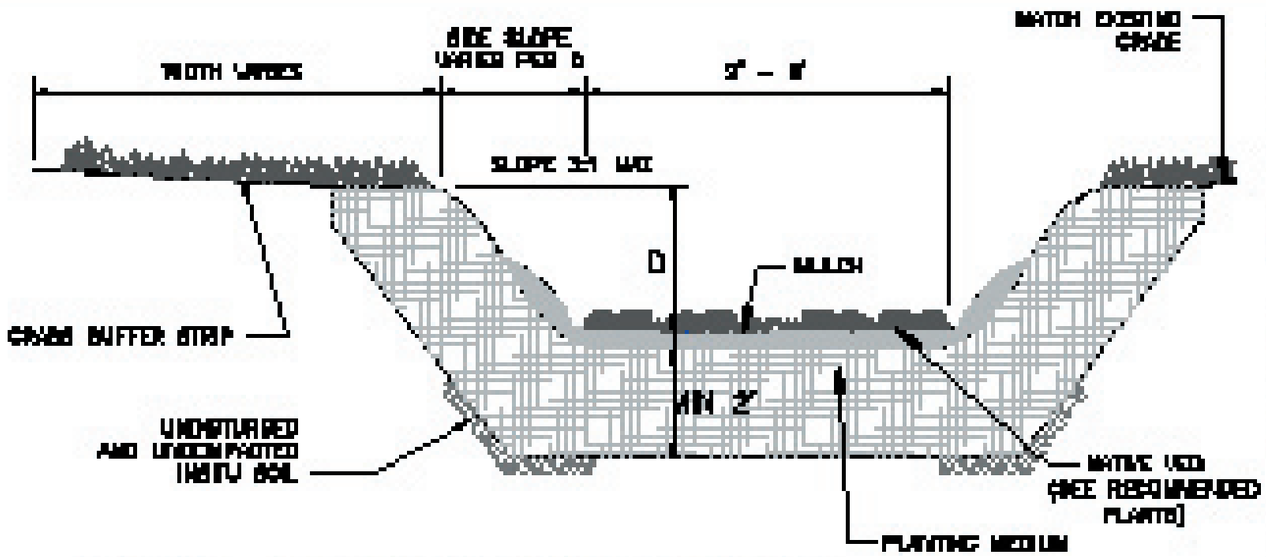
NOT FOR CONSTRUCTION PURPOSES

FILTRATION ONLY FACILITY CROSS–SECTION

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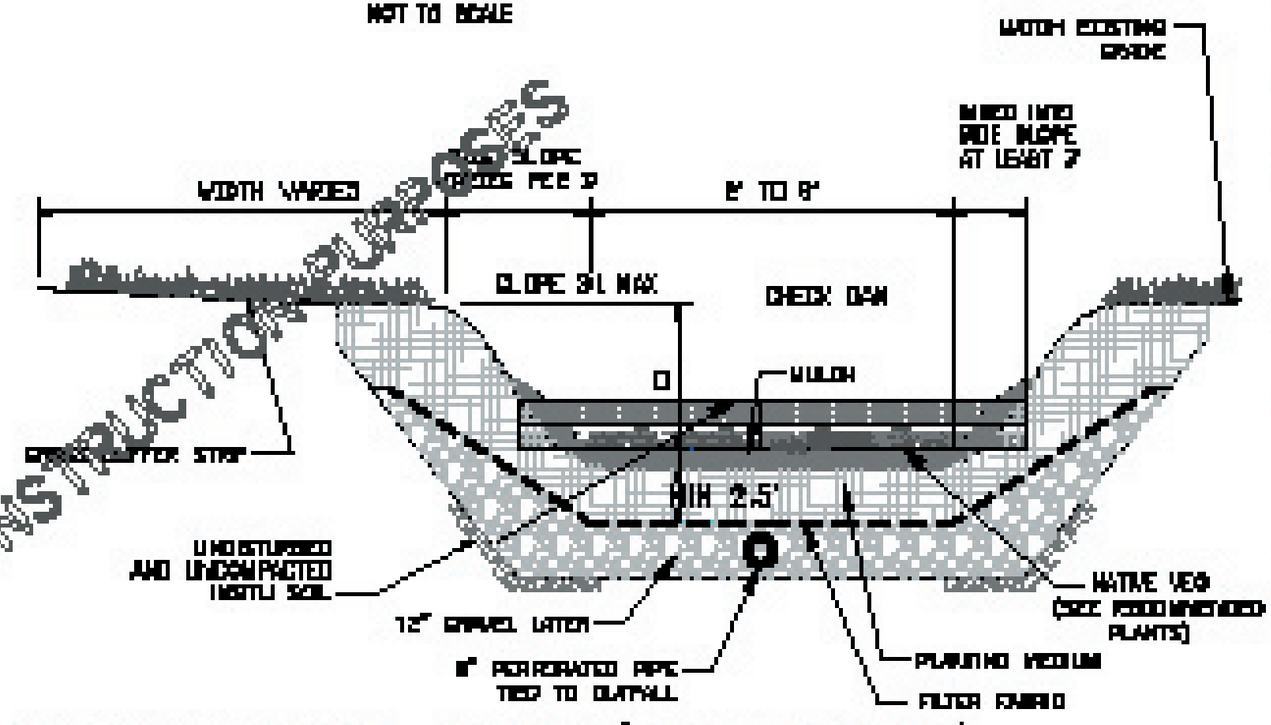
2009 NW HYDRAULIC STORMWATER MANUAL

DETENTION/ FILTRATION ONLY FACILITY



TYPICAL WET SWALE CROSS-SECTION

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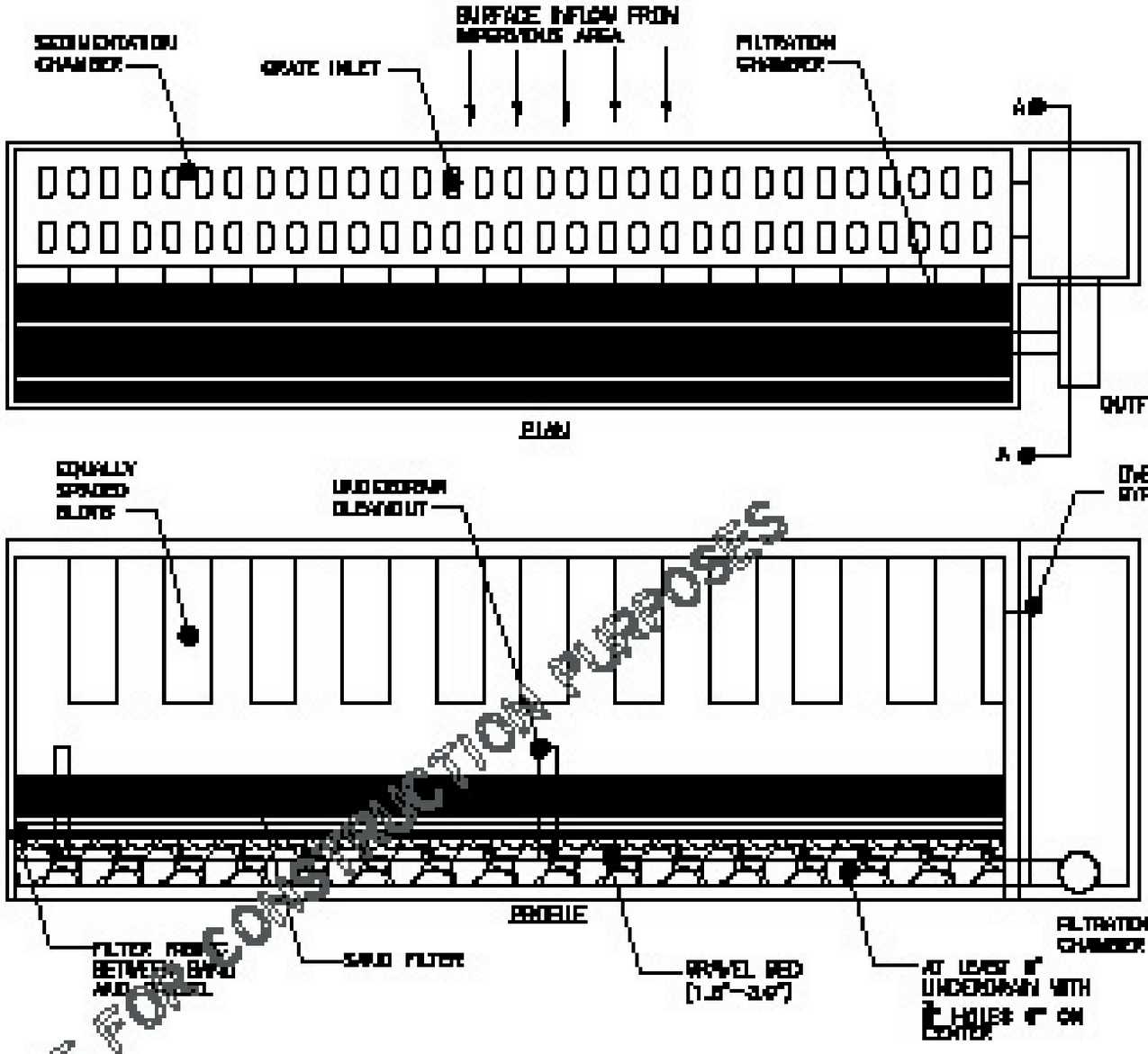
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NOT FOR CONSTRUCTION PURPOSES

2005 NWA MUNICIPAL STORMWATER MANUAL

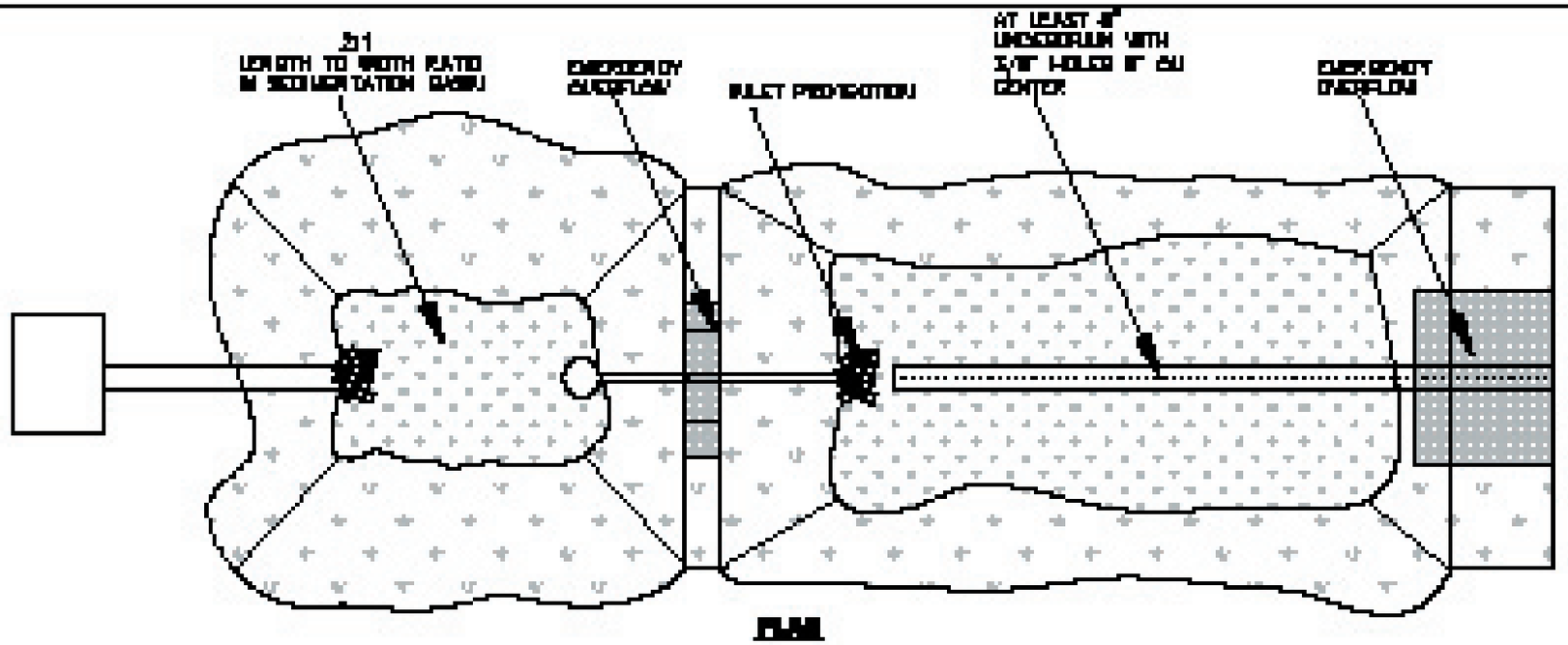
WET AND DRY SWALES

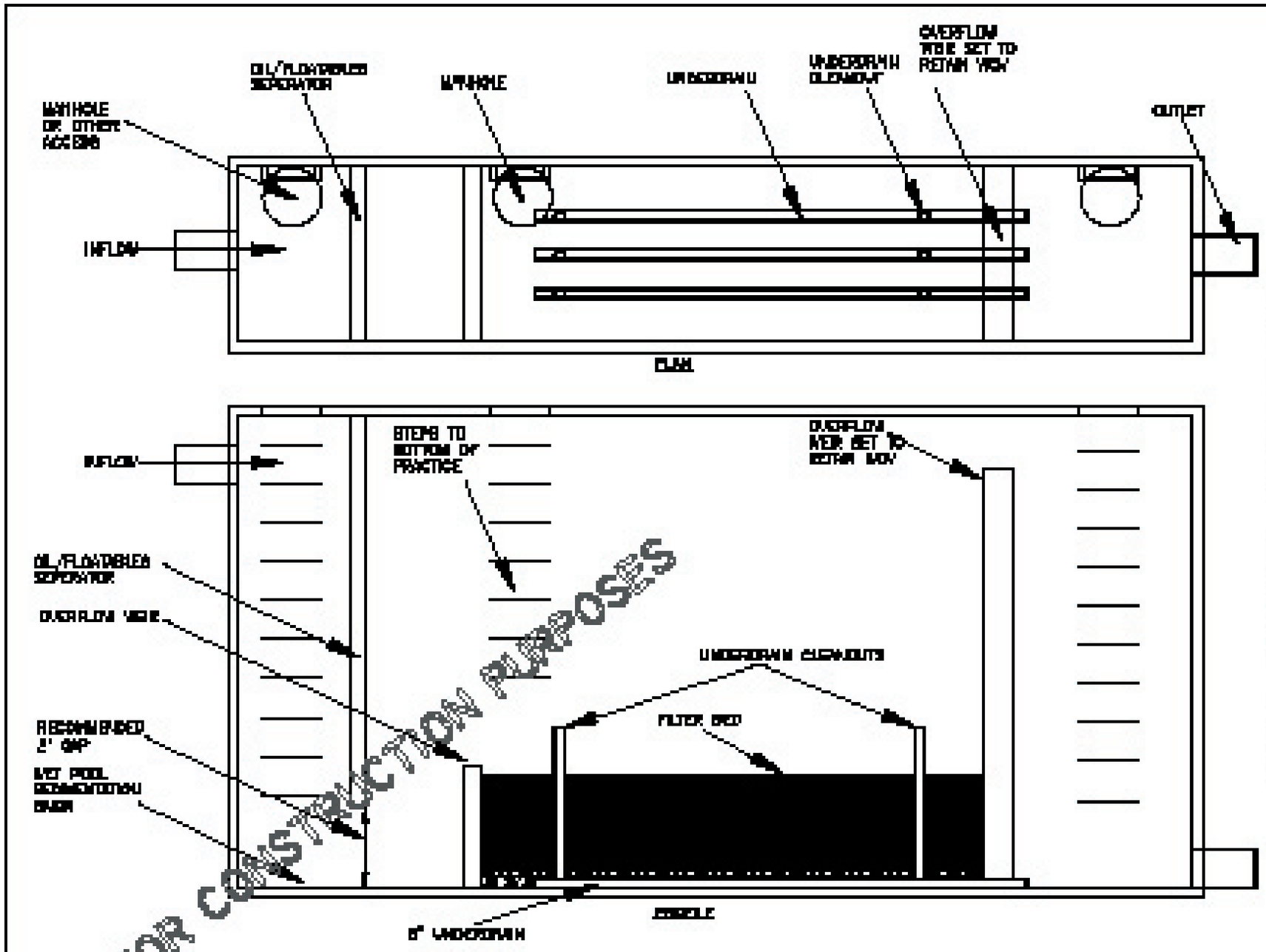


NOT FOR CONSTRUCTION PURPOSES

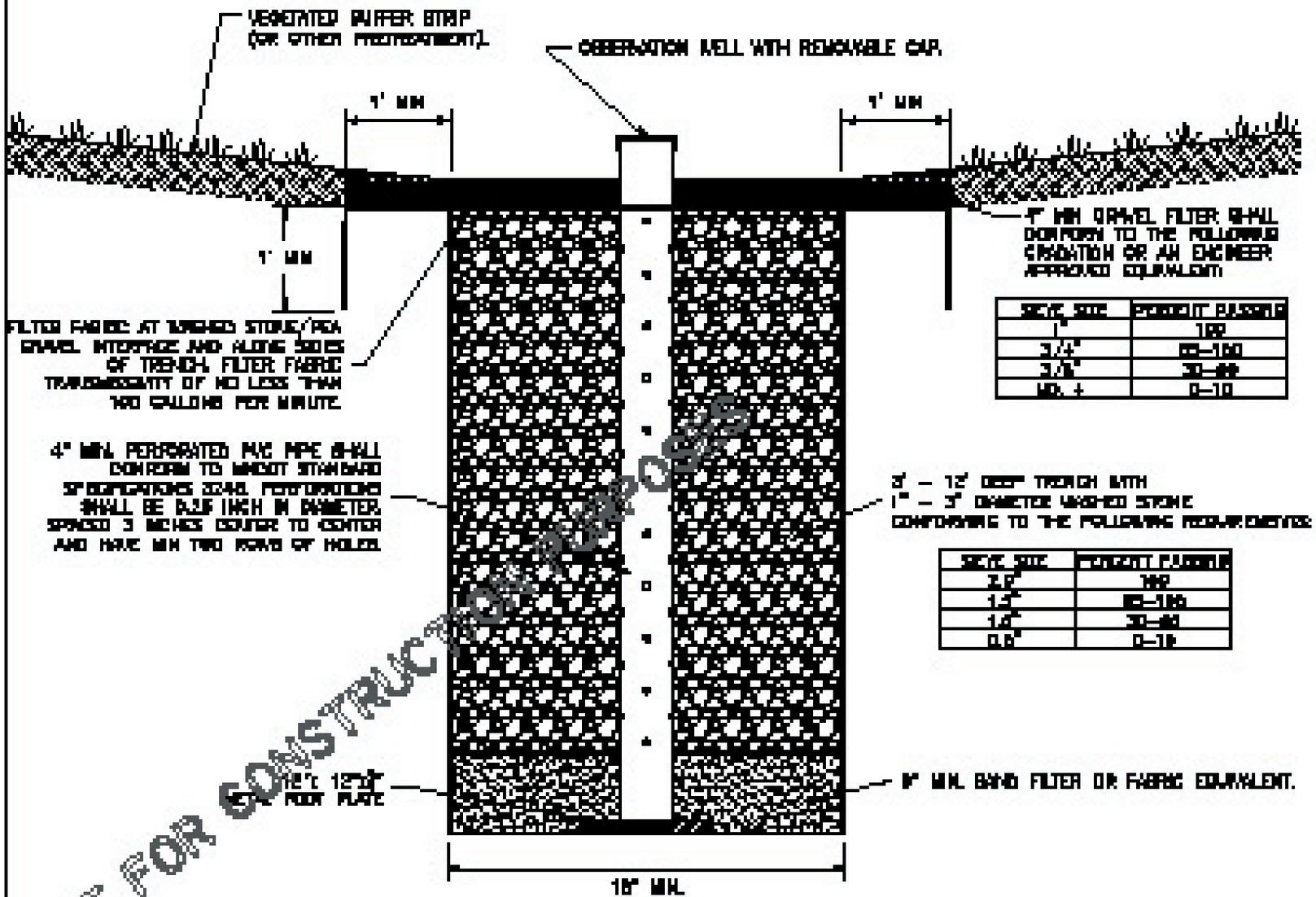
PERIMETER SAND FILTER DETAILS

NOT TO SCALE


2:1
LENGTH TO WIDTH RATIO
IN SEDIMENTATION BASIN
EMERGENCY
OVERFLOW
INLET PROTECTION
AT LEAST 8"
UNDERDRAIN WITH
3/8" HOLES 6" ON
CENTER
OVERSIZED
OVERFLOW
PLAN
USE FLOW DIVERSION TO BYPASS
FILTER FOR VOLUMES GREATER
THAN WATER QUALITY VOLUME.
(SEE DETAIL)
INLET PROTECTION
EMERGENCY OVERFLOW
FILTER FABRIC
ABOVE AND
BELOW BAND
AT LEAST 8"
UNDERDRAIN WITH
3/8" HOLES 6" ON
CENTER
GRAVEL BED
PROFILE
NOT FOR CONSTRUCTION PURPOSES
SURFACE SAND FILTER DETAILS
NOT TO SCALE



NOT FOR CONSTRUCTION PURPOSES



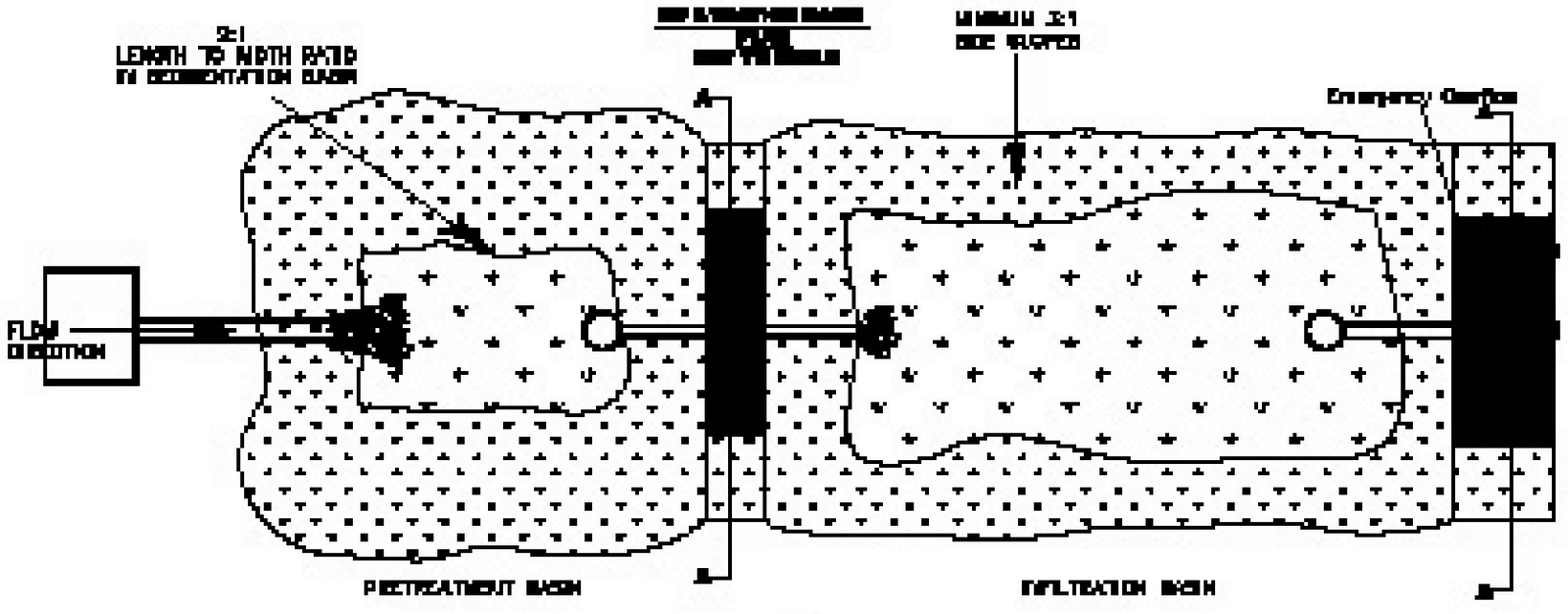
TYPICAL INFILTRATION TRENCH CROSS-SECTION

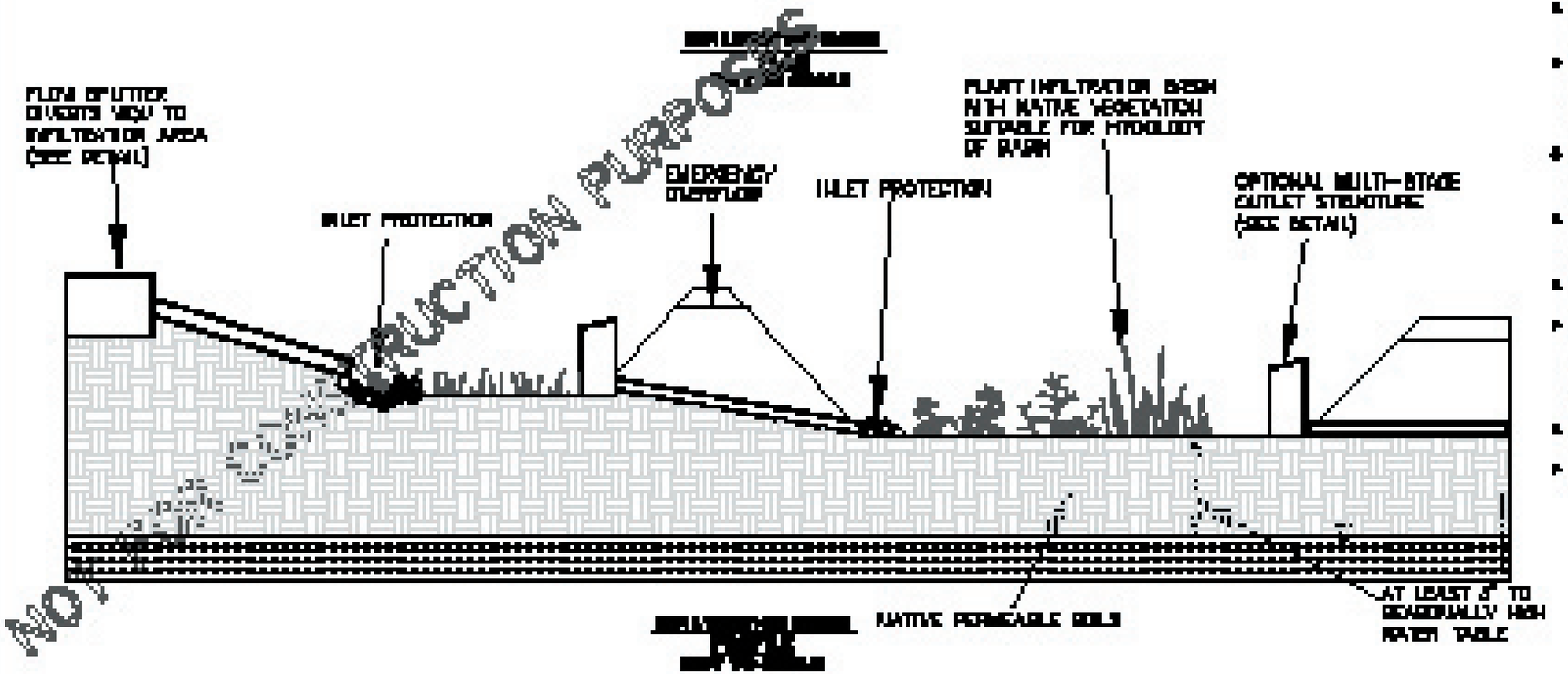
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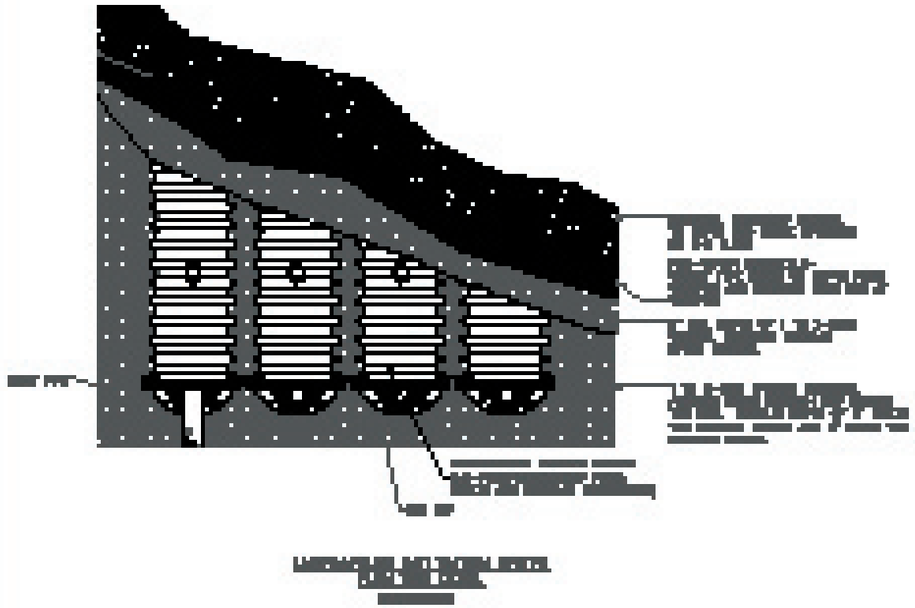
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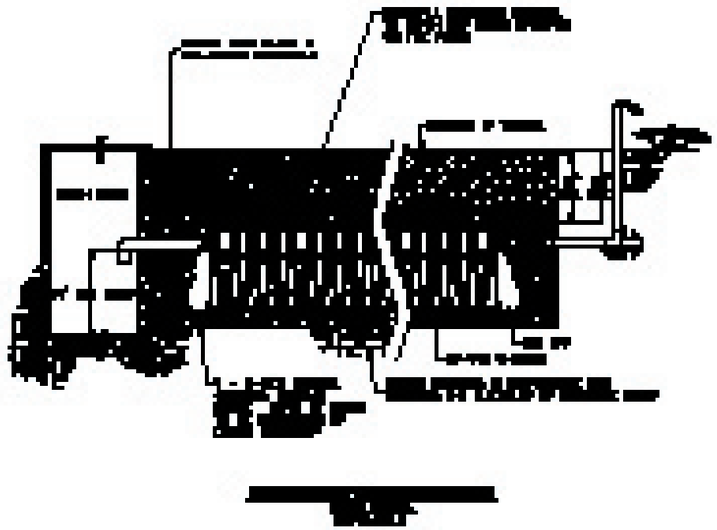
2500 MINIMUM STORMWATER MANUAL

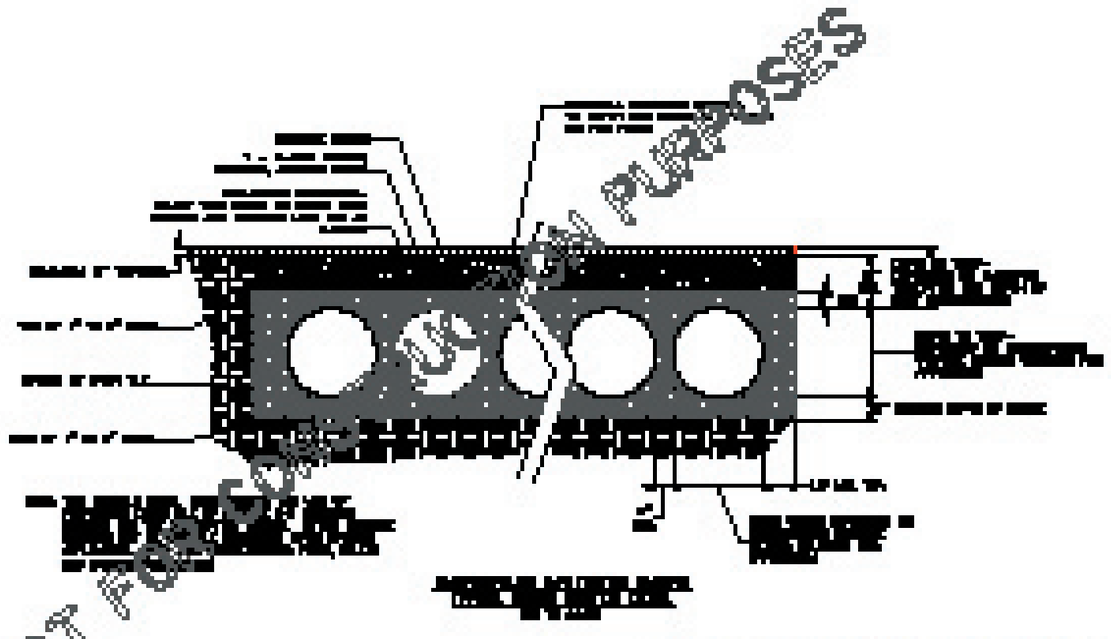
TYPICAL INFILTRATION TRENCH CROSS-SECTION


2:1
LENGTH TO WIDTH RATIO
IN DESIGNATION BASIN
MINIMUM 3:1
SIDE SLOPES
Emergency Overflow
FLOW
DIRECTION
PRETREATMENT BASIN
INFILTRATION BASIN


FLOW SPLITTER
DIVERTS H2O TO
INFILTRATION AREA
(SEE DETAIL)
INLET PROTECTION
EMERGENCY
OVERFLOW
INLET PROTECTION
PLANT INFILTRATION BASIN
WITH NATIVE VEGETATION
SUITABLE FOR HYDROLOGY
OF BASIN
OPTIONAL MULTI-STAGE
OUTLET STRUCTURE
(SEE DETAIL)
NOT FOR CONSTRUCTION PURPOSES
NATIVE PERMEABLE SOILS
AT LEAST 3' TO
SEASONALLY HIGH
WATER TABLE

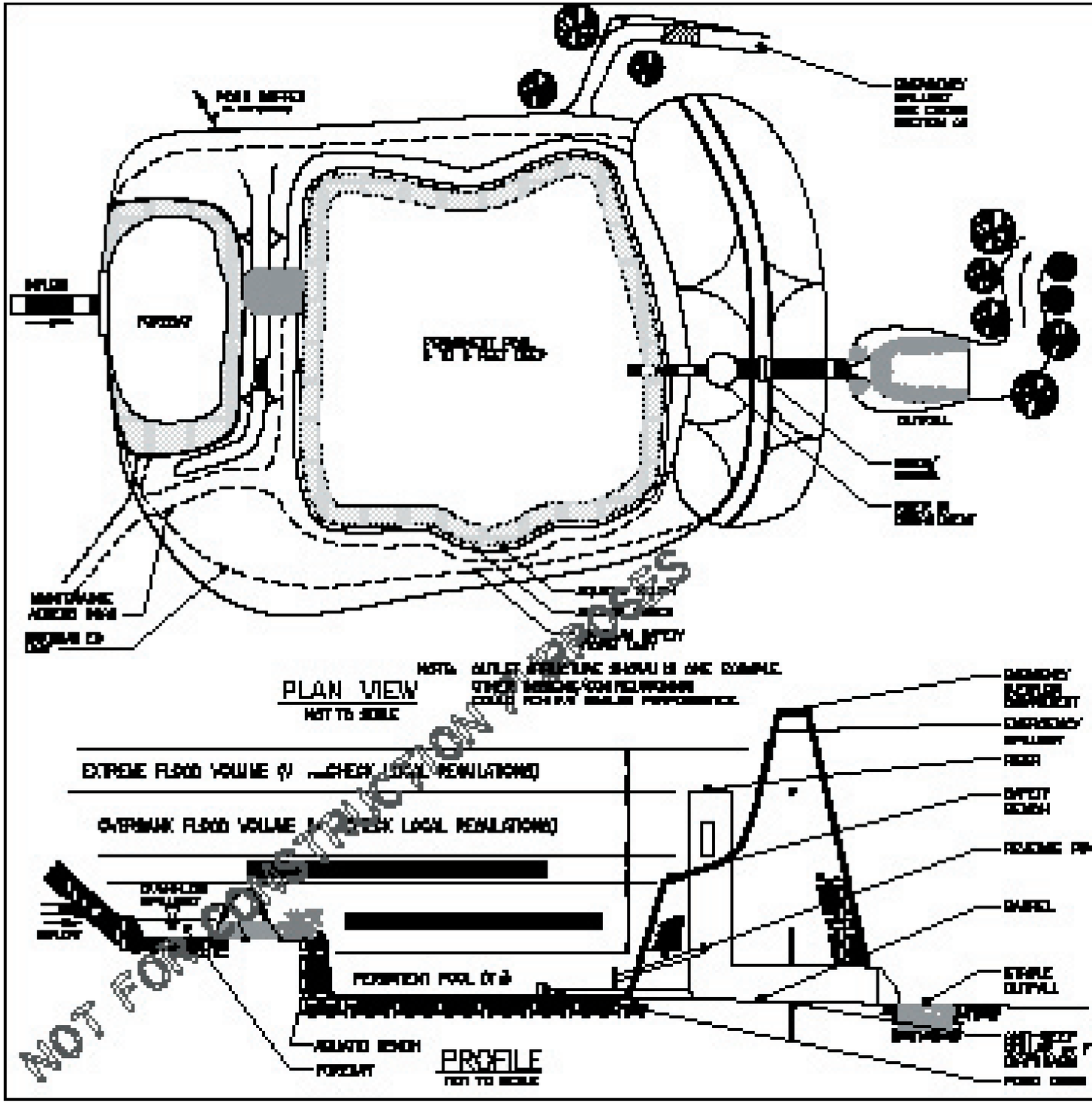






INFILTRATION SUBSURFACE PLANS & PROFILE

NOT TO SCALE

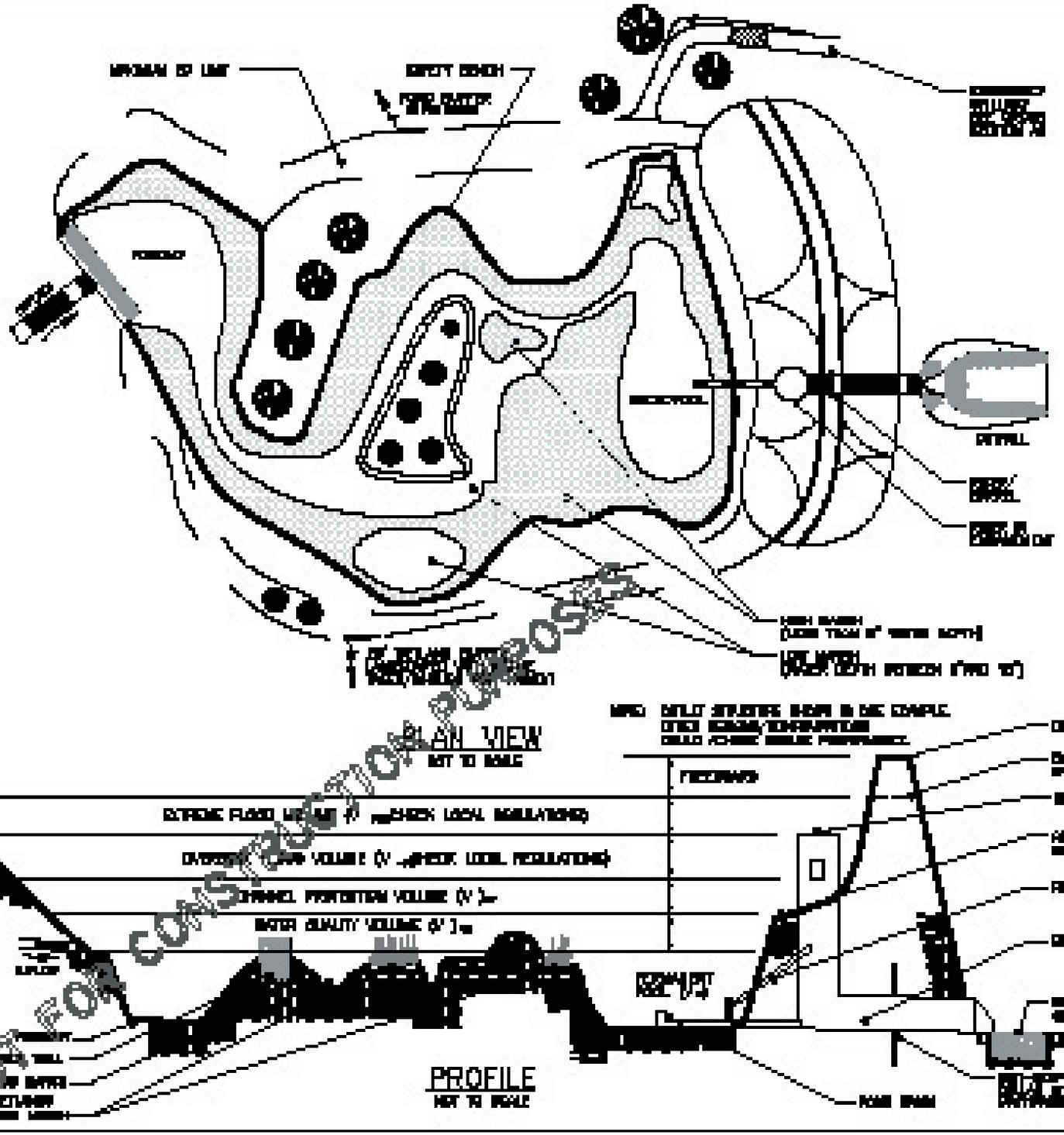


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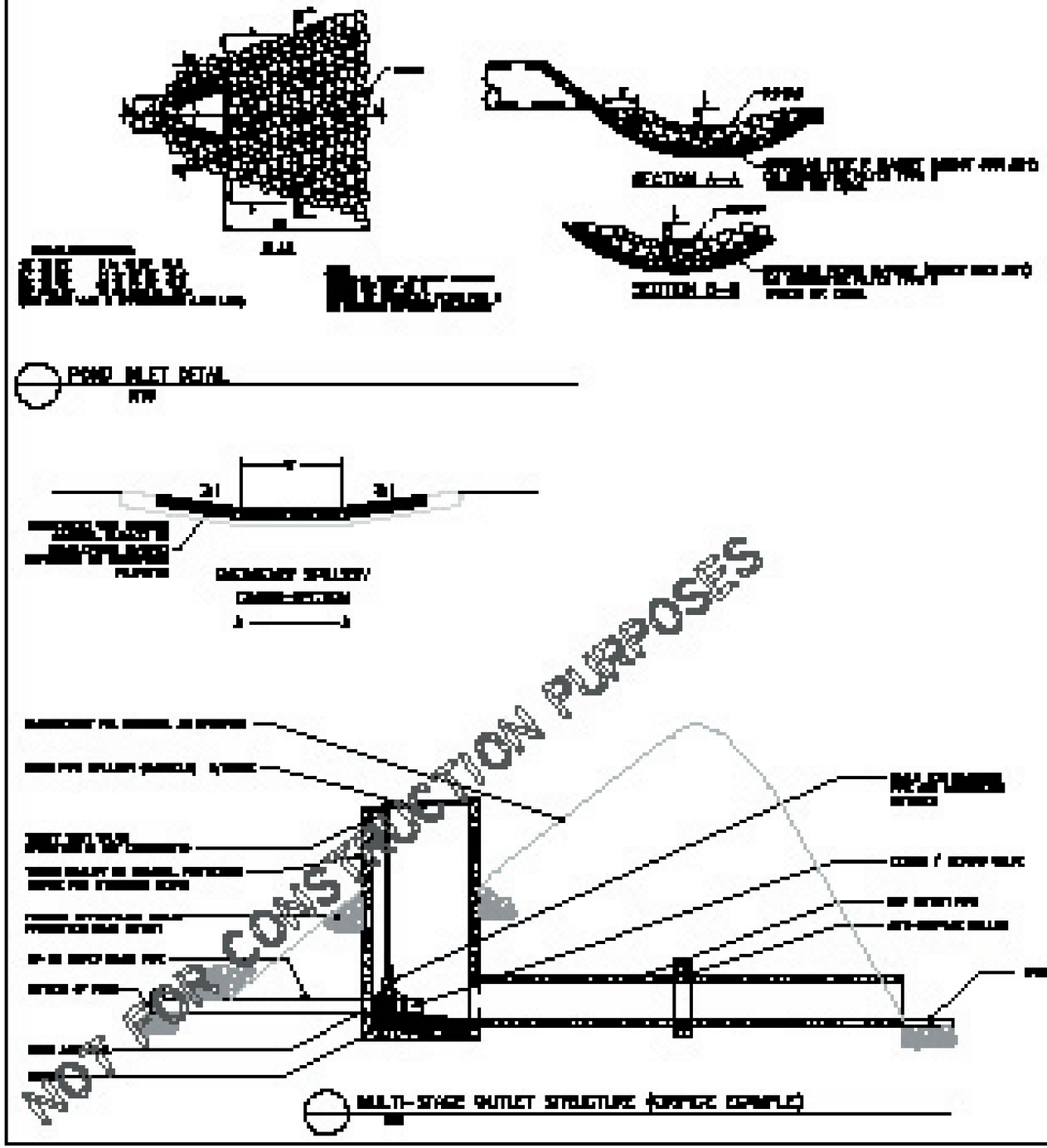
TYPICAL POND PLAN AND PROFILE

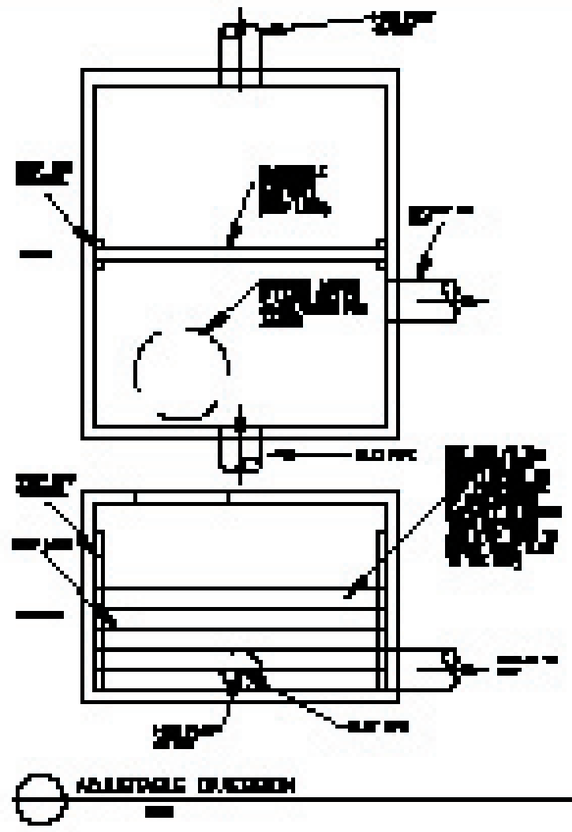
SCALE: AS INDICATED

STORMWATER MANUAL

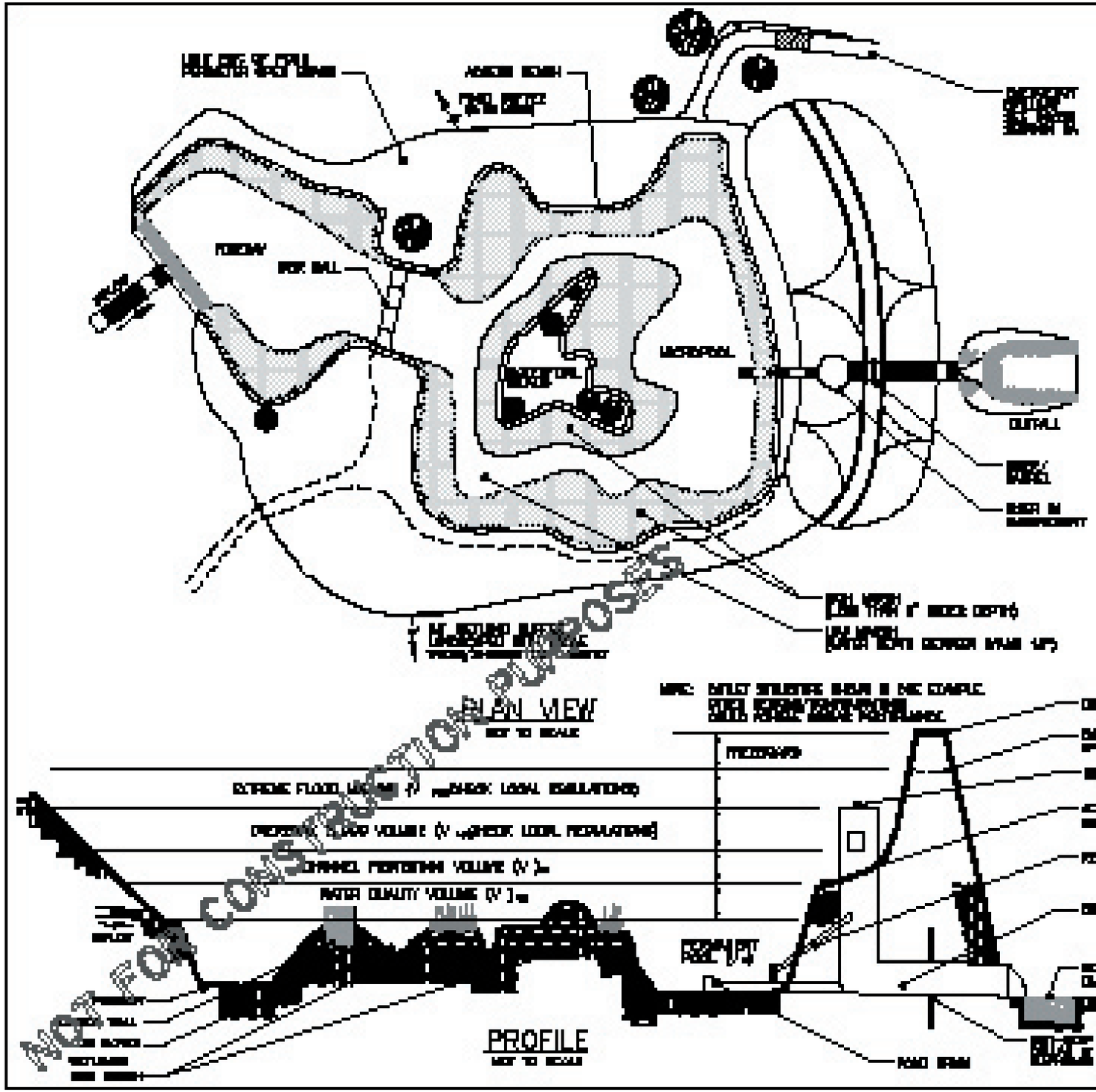


NOT FOR CONSTRUCTION PURPOSES





NOT FOR CONSTRUCTION PURPOSES


PLAN VIEW
PROFILE
NOT FOR CONSTRUCTION PURPOSES

INVER GROVE HEIGHTS
Northwest Area

Appendix B

Stormwater BMPs and Plant Material Selection

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Stormwater BMPs and Plant Management Selection

Appendix B

Key Topics: stressors evaluation and plant material selection, BMP buffer vegetation, pre-treatment sites for infiltration basins, annual maintenance, references

Contents

I. Evaluating Environmental Stress is a Critical Pre- Planning Step to Plan Material Selection..... 3
II. Healthy BMPs Require Vegetated Buffers..... 5
III. Vegetation Operations and Maintenance..... 8
IV. Web Reference for Stormwater BMP Plant Material..... 10
V. Additional References on Plant Material Selection and Maintenance..... 11

I. Evaluating Environmental Stress is a Critical Pre-planning Step to Plant Material Selection

Plant material selection depends on the type of storm water BMP and environmental stressors. Stressors include the levels of various pollutants and moisture and will directly affect vegetation response, health, and effectiveness of the BMP. For these reasons an evaluation of BMP stressors must be considered before selecting plant material. BMP vegetation must be carefully selected and maintained (see subsequent section on Operation and Maintenance) in order for the infiltration function to operate.

The quality of water entering the urban storm water BMP is influenced by the type of runoff surface and expected pollutants. For example, impervious surfaces from major roads will see more vehicle traffic, more potential dirt and grit, more petroleum products, and in northern climates, more sand or salt use for ice management. In contrast, driveways, rooftops, sidewalks and small streets and roads will not typically provide the same amount of pollutant load. The proportion of impervious surface attributed to roads is listed in Table B.1 as one criteria to evaluate and anticipate the stressors for BMP vegetation. The other criteria listed in Table B.1 is the proximity of road runoff to the BMP. For example, the BMP site could be separated by grassed side slopes or buffer strips, be located on minor streets, or be designed to have a pretreatment site. In these cases road runoff is indirect. All buffer strips and pretreatment areas are assumed to have direct road runoff without any filtering. These two criteria combined will determine the anticipated levels of various environmental stressors.

Flooding for more than a couple of days is used as a general cut off point for shifting vegetation from generally intolerant to flood-tolerant. This level of flooding is expected for the infiltration basin and sometimes for vegetated swales. However, the other BMPs are not expected to encounter flooded conditions, if the catchment area is sized appropriately. Salt stress is another burden on the BMP vegetation. Various levels of salt-tolerance must be accommodated based upon the amount of catchment area being treated with salt in the winter. This is distinguished in Table B.1 as 'salt-treated surface as proportion of total impervious' and assumes that not all public road surfaces are equally treated. Salt stress can be buffered to some extent with the appropriate buffer vegetation, except in the design of the parking lot bioretention, in which it is assumed there is no buffer. However, salt and other soluble contaminants are much more difficult for buffers to screen out compared to silt and sand, and so the actual BMP vegetation must still be considered for salt-tolerance (see the last column in Table B.1). Excess nutrient is not listed as a stressor, but may be problematic because several commonly known invasive or undesirable species are more competitive under higher nutrient loads. A healthy buffer should help alleviate this by trapping much silt, which is a carrier for much of the phosphorus in the runoff. The green roof is subject to quite different stressors compared to other BMPs further down the treatment train. Air-borne particulates can be a problem under higher atmospheric pollutant loads, but no information is available in this geographic region to compare green roofs with and without this load. Drought and heat stress are well studied stressors and green roof selections shall need to consider this.

Table B.1 Wetland Management Standards								
BMP	**Road Surface as proportion of total impervious (low, medium, high)**	**Proximity of road runoff (direct, indirect)**	**Environmental stressor (salt, petroleum, flooding, silt, sand, drought shown where applicable)**					**Salt-tolerant requirement (low, medium, high)**
			Silt/ Sand	**Salt**	**Petroleum**	**Flooding**	**Drought**	
Infiltration basin (several days standing water)	Medium	Indirect		Salt	Petroleum	Flooding		Medium
Infiltration trench	High	Direct		Salt	Petroleum			High
Rain Garden	Low	Indirect		Salt	Petroleum			Low
Parking lot bioretention	High	Direct	Silt/sand	Salt	Petroleum			High
Vegetated swale – dry Infiltration and biofiltration		Indirect via grassed buffer		Salt	Petroleum	Flooding		Low to medium
Vegetated swale – wet (several days standing water)		Indirect via grassed buffer		Salt	Petroleum	Flooding		Low to medium
Buffer strip for rain garden, vegetated swale, infiltration trench	Low to high	Direct	Silt/sand	Salt	Petroleum			High
Infiltration basin pretreatment basin	High	Direct	Silt/sand	Salt	Petroleum	Flooding		High
Green roof	n/a	n/a	Air-borne Particulates				Drought and Heat	n/a

II. Healthy BMPs Require Vegetated Buffers

Every BMP that might encounter higher pollutant loads and environmental stress will require a pretreatment buffer area. In the case of infiltration basin, a volume control pretreatment basin can provide the settling capacity for much of the heavier particles to be removed. Still, salts will not be removed in this process. A variety of swale and trench type BMPs might be located so as to accommodate vegetated buffers to filter out some of the products in direct road runoff, particularly in drainage areas with a high proportion of higher traffic roadways.

BMP buffer vegetation selection as well as the operations and maintenance schedule are different from the other BMPs.

BMP Buffer Vegetation for the Rain Garden, Vegetated Swale, and Infiltration Trench

The BMP buffer is often edges of roads and sidewalks. Salt stress may be a problem. Cultural practices often dictate that the buffer strip also be mowable grass. Trampling and pet waste may be additional stressors. They tend to be shallowly sloped and thus not subject to flooding. From multiple stressors, the lifespan may be short or the health poor for the BMP buffer. The potential for frequent reseeding and mowing dictates that plant selection is best focused on function under high stress and low cost. A simple mix of tolerant grasses is thus recommended.

Summary of Criteria for BMP Buffer Plant Selection

- Inexpensive seed source
- Compatible species (similar growth and colonizing rates)
- Tolerant of the anticipated environmental stress (see table above)
- Short-lived perennial grasses – long life span not needed (long-lived perennials OK where environmental stressors are low)
- Amenable to mowing

Plant selection is not to be limited to native species. Buffer sites are also assumed to be slightly sloping without opportunity for ponding, and with substrate that is well-aerated and porous. Different sites should be tested with different mixes or species to see what works best.

Looking In-Depth at Salt Tolerance for BMP Buffers

Mn/DOT funded the production of a handbook on the principles of integrated roadside vegetation management (IRVM). This handbook provides some guidance on nonnative turf species which are feasible for high salt stress. The internet access for this publication is http://www.lrrb.gen.mn.us/PDF/200019.pdf The full citation is in the Vegetation References. Below is the recommended nonnative turf seed mix for salt-tolerance. The 2005 Mn/DOT technical report that summarizes all of their seed mix numbers now gives the following as seed mix 260.

A report titled *Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice* is available through Mn/DOT's Office of Research Services. The report outlines many maintenance and construction activities to use in Minnesota.

Source: 2005 Mn/DOT Technical Report

To alleviate the effects of roadway salt on adjacent soil and vegetation, treat the soil with gypsum, which reverses the effects of salt and sodium accumulation, and plant a salt-resistant or alkali grass. Mn/DOT has developed a new low-maintenance turf seed mix, 60A (Modified 60B), for use in areas with high salt, the composition of which is shown below. This grass reaches a height of about 12 inches. The application rate is 100 pounds per acre.

Common Name	Botanical Name	Percent of Mix
Fescue, creeping-red "Cindy"	Festuca rubra	10.0
Rye-grass, perennial "Elf"	Lolium perene	14.0
Bluegrass, Canada "Reubens"	Poa compressa	12.0
Bluegrass, fowl	Poa palustris	10.0
Bluegrass, common "98/85"	Poa pratensis	12.0
Bluegrass, Kentucky "Park"	Poa pratensis	12.0
Bluegrass, Kentucky "Caliber"	Poa pratensis	10.0
Alkali grass, "Salty"	Puccinella distans	19.0
White clover	Trifolium repens	1.0
	Total	**100.0**

The following natives or wildflowers can also be used with success in areas where salt is an issue:

Native grasses: Canadian wild rye, Indian grass, little bluestem, blue grama, side oats grama
Wildflowers: Black-eyed Susan, purple prairie clover, yarrow, bush clover

A report titled *Establishment, Protection, and Reestablishment of Urban Roadside Vegetation Against Salt and Ice* is available through Mn/DOT's Office of Research Services. The report outlines many maintenance and construction activities to use in Minnesota.

Native plant seed mixes may also be amenable to BMP buffers. This list of seed mixes may be considered.

- BWSR Mixture U10 – native berm
- MNDOT Mixture 350NGR – general purpose roadside (taller stature)
- MNDOT Mixture 30B – urban prairie (shorter stature, ca. 18 inches – no mowing)

Following is a list of individual species considered as salt-tolerant.

- Blue grama grass (Bouteloua hirsuta)
- Buffalo grass (Buchloe dactyloides)
- Little bluestem (Schizachyrium scoparium)
- Tall wheatgrass (Agropyron elongatum)
- Western wheatgrass (Elytrigia smithii)
- Alkali grass varieties Fults and Salty (Puccinella distans) – sod-forming
- Red fescue varieties Dawson and Cindy
- Park Kentucky bluegrass
- Low Maintenance Kentucky bluegrass

Seed source may play an important role in providing salt tolerance. Producers from northwest Minnesota and eastern North Dakota may likely be carrying local seed with more natural salt tolerance than the same

seed from fields in other areas. This is thought to be the case because of naturally higher salt levels which can be found in certain of the region.

BMP Buffer Vegetation as Pre-treatment for the Infiltration Basin

The pre-treatment basin is subject to environmental stressors shown in Table B.1, but unlike grass buffer strips is usually offset from sidewalk and road surfaces and the additional stressors mentioned above. Cultural requirements for mowing are not a factor in plant selection. They are however subject to flooding and therefore require a distinct selection of vegetation compared to the grass BMP buffer.

The pre-treatment function is to settle out sediment prior to the runoff reaching the infiltration site. As such the vegetation will need to be replaced once the settling function declines. This schedule will be determined by performance evaluated under operation and maintenance plan.

The best recommendation for the pre-treatment basin is a seed mix composed of compatible species. This introduces a range of plant tolerances to various stressors. The species which survive are best suited to the site. Different mixes should be tried at different sites to test what is best suited to the general site conditions.

Pre-treatment basin recommended seed mixes:

- BWSR Mixture W4 – native swale/ditch
- MNDOT Mixture 28B – general purpose native ditch
- MNDOT Mixture 328NEP – economy pond/ditch

It may be of interest to have a list of individual plant species suitable for these sites. A list was derived by screening the MPCA publication “Plants for Storm water Design’, because it provides a guide to flooding tolerance. The list in that manual is too broad and does not address the additional environmental stressors identified above. It is also limited to recommendations for rain gardens and vegetated swales (unspecified type).

The list provided here resulted from first screening the MPCA list according to flooding frequency – medium, depth – 12-24 inches , and duration – up to 4 days (herbaceous vegetation only) and then screening for tolerance to the additional environmental stressors.

- Panicle aster (Aster lanceolatus)
- Swamp aster (aster lucidulus)
- New England aster (Aster nova-angliae)
- Red-stemmed aster (Aster puniceus)
- Boltonia (Boltonia asteroides)
- Fringed brome (Bromus ciliatus)
- Awl-fruited sedge (Carex stipata)
- Fox sedge (Carex vulpinoidea)
- Canada wild rye (Elymus Canadensis)
- Virginia wild rye (Elymus virginicus)
- Joe pye weed (Eupatorium maculatum)
- Boneset (Eupatorium perfoliatum)
- Switchgrass (Panicum virgatum)
- Brown-eyed susan (Rudbeckia subtomentosum)
- Woolgrass (Scirpus cyperinus)
- Mad-dog skullcap (Scutellaria lateriflora)
- Cup plant (Silphium perfoliatum)
- Blue vervain (Verbena hastata)

III. Vegetation Operations and Maintenance

Recognizing Healthy Vegetation

Plant health vigor is integral to BMP function. Public works crews must be trained on the signs of vigor and symptoms of stress, as well as how the vegetation functions as part of the stormwater management system. What does vitality and vigor look like? And how is this related to BMP function?

BMP Vegetation

The following qualitative descriptions are expected for healthy BMP vegetation.

- ► Soil surface is fully covered by living shoots without patches of thatch or sediment
- ► Herbaceous vegetation forms a dense stand
- ► Undesirable species are not present
- ► Herbaceous vegetation forms even-height patches of green shoots – no patches of yellowing, sparse, or stunted vegetation

The above descriptions allow the vegetation to function for storm water management in the following ways:

- ► Provide full surface area of the BMP for storm water contact with the soil surface (surface thatch and sediment deposits act as a barrier)
- ► Provide well-aerated, living root zone for storm water to quickly infiltrate the soil (water transport requires a well-aerated, honeycombed soil matrix; a vigorous root system allows for plant water uptake in between runoff events)
- ► Provide a high roughness coefficient of herbaceous shoots to trap and slow above ground runoff
- ► Last but not least, vigorous vegetation is the basis for a tidy and visually pleasing community amenity

BMP Buffer Vegetation

Staff Training

Operations and maintenance will require the skills of evaluating vegetation health and maintaining vegetation health. The recommendations for developing staff training are provided below.

Training Programs

- ► Summer staff ½-day workshop – conducted annually to prepare seasonal vegetation specialists
- ► Professional staff kickoff 1-day workshop to prepare professional vegetation specialists
- ► Professional staff annual ½-day update workshop / conference

Training Content (comprehensive; break out according to supervisor or seasonal position)

- ► Selecting vegetation health indicators: the equivalent of blood pressure, height, weight, and health history
- ► Measuring health indicators: knowing what to look for in the field, how to take and record the measurements, field-determined decisions on when to schedule the next check-up
- ► Developing a detailed procedural book
- ► Record keeping of health indicators: storing field sheets, electronic database design and data storage
- ► Evaluating health records: using data to graph, tabulate a meaningful picture of what is going on
- ► Surgery and intervention: what, when and how of removing undesirable vegetation; unhealthy sediment

deposit removal; reclaiming bare areas with seed and seedlings; where to deposit weed flowering heads, stalks, and roots
- Practicing surgical technique: a practicum on de-heading, uprooting, manual seeding and planting, surgery without trampling
- Nursing young vegetation: when watering is needed, hand weeding
- Maintaining health of soils in the BMP buffer
- BMPs amenable to burning: examples of small-scale burns, fire department training practice, when thatch should be burned
- Dogs, cats, snowmobiles, and other visitors: trampling and compaction, ammonia damage, accidental mowing
- Costs and budgeting: labor, materials, administration
- Adopt-a-BMP: when and where this is feasible; who will administrate it?
- Supervisor Resource Library: where to go for contractors and plant materials; assisting City staff to create public information fact sheets
- Professional training: keeping up with technology and advances; networking and sharing experience; in-house training – brown bags for City staff

Annual Maintenance

Monitoring and maintenance is to be divided between supervisors and seasonal staff. Supervisors will have more in-depth initial training/education from which to make decisions, and gain in-depth knowledge from year-to-year experience. Seasonal staff can be quickly trained each season, and perhaps a seasonal, permanent position can be created in lieu to coordinate with the year-round, permanent supervisor. Job descriptions and positions may be somewhat dynamic when the stormwater maintenance program is initially adapting.

Provided below is a generic schedule of monitoring and maintenance activities, with recommended staff assignment given in parentheses. In some cases a contractor is recommended for carrying out a task, which could include other City staff or volunteers as the contractor. In general the supervisors are responsible for measuring the standard health indicators, and documenting miscellaneous observations which suggest the onset of some health decline, whether it be a certain species or the whole site. The seasonal staff can perform the tasks which are clear cut and requiring minimal judgement.

Maintenance, monitoring is a preventive health plan. Falling behind may quickly lead to compounding plant stress and a spiraling of effects on plant health. It is critical not to fall behind on the schedule; skip months, etcetera. Some invasive species are very easy to control IF they are not allowed to reproduce. For example, once weed seed is incorporated into the ground or perennial weed roots have been allowed to expand, then the eradication is escalated many-fold.

The ongoing maintenance is going to be distinctly different for the BMP and BMP buffer, as detailed below.

BMP Vegetation

- April: observe for thatch build up that prevents light penetration to the soil surface; make recommendation to burn or not. (supervisor) and burn (contractor)
- April/May: Observe for sediment deposits after spring snowmelt and flooding (supervisor); scrape or rake all areas with a surface covering to loosen the deposit (seasonal); remove or incorporate into underlying soil (seasonal)
- May/June: Observe for bare spots and lack of new spring growth (seasonal); as needed, determine seed or seedling requirements (supervisor); hand cultivate and sow seed (seasonal), or mechanically prepare and seed areas larger than 100 square feet (supervisor or contractor)
- Early July: Observe for undesirable species - MDA exotic species tables – typically seedlings of common buckthorn, box elder, reed canary grass, purple loosestrife, thistle, burdock, but also cattail

shoots, willow shoots (supervisor); loosen all roots and pull shoots and roots by hand or with weed wrench (seasonal).

- ► September: observe for artificial debris and remove: cigarette butts, bottle caps, plastics, glass shards, bits of paper, etc. - applies to the BMP buffer too (seasonal or contractor)
- ► September/October: Observe for additional bare spots other than areas receiving sediment build up from snowmelt (supervisor); hand cultivate and sow seed (seasonal), or mechanically prepare and seed areas larger than 100 square feet (supervisor or contractor)

Note that fertilizer treatment is not prescribed. Fertilizer provides an advantage to undesirable species which thrive better in more nutrient-rich conditions.

Each BMP site will vary on the kind and amount of pollutant load and factors such as soil, moisture, solar exposure, winter cold snaps, summer droughts, and compaction by foot traffic and snowmobiles. These factors will affect the year to year vigor of the BMP vegetation. Supervisors will quickly learn which stressors are most affecting a particular site.

BMP Buffer Vegetation

Rain gardens and vegetated swales require a buffer between the pavement runoff and the BMP. Conceptual BMP designs display this as a uniform mowed grass buffer. The buffer strip must receive the same level of monitoring and maintenance as the BMP vegetation. A vigorous buffer strip will prolong the life of the BMP by providing a pre-treatment phase and taking the brunt of the stress from sediment load and salt runoff. Even with good maintenance, periodic replacement may be needed. Salt can build up in the soil to intolerant levels over time. Scraping the vegetation, treating the soil with gypsum, and then replanting may be necessary.

BMP Buffer turf monitoring and maintenance may follow turf management practices. Depending on location and surrounding use, the mowing can be set high. This will provide additional roughness to trap runoff, but this will have to be decided according to whether the roughness backs up water in places where it is not wanted, like adjacent curbs and sidewalks.

Preventive maintenance activities for turf:

- ► Sediment scraping and removal
- ► Plug Aeration
- ► De-thatching
- ► Re-seeding, especially bare and stressed points where weeds begin
- ► Mulch Mowing
- ► Fertilizing

If the BMP buffer is a native clump grass, then monitoring and maintenance is more akin to short grass prairie management.

- ► Burning
- ► Scraping and hand seeding
- ► No fertilizing – native grasses are good nutrient scavengers
- ► Sediment scraping and removal
- ► Plug Aeration

IV. Web References for Stormwater BMP Plant Material

The following agency websites provide information on plant material selection for vegetated storm water BMPs.

From the Minnesota Pollution Control Agency:

http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html Appendix E

From the Minnesota Pollution Control Agency:
http://www.pca.state.mn.us/publications/manuals/stormwaterplants.html

From the Rice Creek Watershed District:
http://www.ricecreek.org and click on the Best Management Practices browser

From the Minnesota Department of Transportation:
http://www.dot.state.mn.us/environment/pdf_files/SeedingManual2003.pdf

From the Minnesota Board of Water and Soil Resources:
http://www.bwsr.state.mn.us/wetlands/publications/nativewetveg.pdf Seed Mix: BWSR W4 for ditches and wet swales

These site are for reference only. Actual site design must be discussed with and performed by professionals with expertise in design and maintenance of storm water BMPs.

V. Additional References on Plant Material Selection and Maintenance

The following references will provide background for designing both plant selection and maintenance programs.

Daubenmire, Rexford. 1968. Plant Communities: A Textbook of Plant Synecology. Harper & Row. New York, NY.

Methods of measuring plant vigor and stand characteristics

Jacobson, Robert L. 2005. Guidelines for Restoring and Managing Native Wetland Vegetation. MN/BWSR and MN/DOT. March 2005.

Although focused on wetlands, provides seed mixes that can be appropriate, in particular mixtures W4, U11.

Johnson, Ann M. 2000. Best Practices Handbook on Roadside Vegetation Management. Mn/DOT Report No. 2000-19. September 2000.

There is excellent information depicting the noxious weeds and use of herbicides; a salt-tolerant turf mix is provided also. Appendix C provides a good summary of nonnative grass species and their use.

MNDOT. 2005. Standardization of Seed Mixes from Previous Standard Specifications for Construction Editions Prior to and Including 2000. Tech Mem. No. 05-03-ENV-01. Jan 18, 2005.

Recommended uses provided and all feasible seed mixes listed; gives BMP buffer (use sod-like turf mixes) and BMP mixes (use native mix for wetter as and ditch/infiltration ponds)

NRCS. 1986. Engineering Field Handbook Chapter 7. Grassed Waterways. March 1, 1986.

In Exhibit 7-2 is nice coverage on the vegetation condition associated with different Mannings N values for degree of retardance of water velocity. This is useful for demonstrating the effect of mowing height and vegetation density on retarding water flow. Best for use in BMP buffer management.

USDA. Veg Spec: Creating Vegetative Designs. USDA, USACE, USGS

http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm

This is a design module based upon the soil physical characteristics at the site; provides you a full list of plant species that fit the soil type and climate of your location; choice of introduced, native, or both species

INVER GROVE HEIGHTS
Northwest Area

Appendix C

Acronyms, Symbols, and Glossary

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Acronyms, Symbols, and Glossary

Appendix C

Contents

I. Acronyms..... 3

II. Symbols..... 6

III. Glossary..... 8

I. Acronyms

BMP – best management practice

BWSR – Board of Water and Soil Resources

cfs – cubic feet per second

CGP – construction general permit

CMP – corrugated metal pipe

CN – curve number

C/O – commercial/office

CWP – Center for Watershed Protection

DA – drainage area

DNR – Minnesota Department of Natural Resources

du – dwelling units

ED – extended detention

EOR – Emmons and Olivier Resources, Inc.

EPA – U.S. Environmental Protection Agency

FEMA – Federal Emergency Management Agency

fps – feet per second

GP – Minnesota Construction General Permit (2003)

GW – ground water

HDR – high density residential

HSG – hydrologic soil group

HS – hotspot

I&M – inspection and maintenance

IPM - integrated pest management

LDR – low density residential

LGU – local governmental unit

LID – low impact development

MDH – Minnesota Department of Health

MDR – medium density residential

MGS - Minnesota Geological Survey

MMCD - Metropolitan Mosquito Control District

Mn/DOT – the Minnesota (state) Department of Transportation.

MPCA – Minnesota Pollution Control Agency

M.S. - Minnesota Statutes

MS4 – Municipal Separate Storm Sewer System under the Phase II NPDES program

NaCl – sodium chloride or common table salt used for roadway deicing.

NFIP – National Flood Insurance Program

NOAA – National Oceanic and Atmospheric Administration

NPDES – National Pollutant Discharge Elimination System

NRCS – U.S. Department of Agriculture, Natural Resource and Conservation Service (formerly the SCS – Soil Conservation Service)

NWI– National Wetlands Inventory

NWL – normal water level

NWS – National Weather Service

NURP – Nationwide Urban Runoff Program

O&M – operation and maintenance

OHWL – ordinary high water level

P – phosphorus

P–8 – Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds

PSH – Potential stormwater hotspot

PWI – Public Waters Inventory

RCP – reinforced concrete pipe

ROW – right of way

SD – separation distance

SCS – Soil Conservation Service (now the Natural Resource and Conservation Service)

SDWA – Safe Drinking Water Act

Sol P – soluable phosphorus

SFR – single family residential (land use)

SIC – Standard Industrial Classification

SPT – standard penetration test

SW – surface water

SWCD – Soil and Water Conservation District

SWMM – Storm Water Management Model

SWPPP – storm water pollution prevention plan/program

TDS – total dissolved solids

TMDL – total maximum daily load

TN – total nitrogen

TP – total phosphorus

TP–40 – Technical Publication 40

TR–20 – Technical Release Number 20: Computer Program for Project Formulation Hydrology

TR–55 – Technical Release Number 55: Urban Unit Hydrology for Small Watersheds

TSS – total suspended solids

TURM – Thermal Urban Runoff Model

USACE – United States Army Corps of Engineers

U.S.C. - United States Code

VCS -- volume control standard

WCA– Minnesota Wetland Conservation Act

WD – Watershed District

WLF – water level fluctuation

WMO – Water Management Organization

WNV - West Nile Virus

WQ – water quality

WSEL – water surface elevation

II. Symbols

A = average basin area

A_i = effective infiltration area at half the volume of the practice

A_f = surface area of filter bed (ft^2)

As = sedimentation basin surface area (ft^2)

A_{VCS} = orifice area

C = discharge coefficient

C = orifice coefficient (0.6 is typically used, but may not apply in all cases)

d_f = filter bed depth (ft)

d_f = filter bed depth (ft)

D = maximum depth of practice

E = trap efficiency

$E_{PermPool}$ = elevation of the permanent pool (the invert of the VCS orifice).

E_{vcs} = the VCS pool elevation

g = gravitational acceleration.

h_f = average height of water above filter bed (ft)

hs = height in sedimentation chamber

h_{temp} = temporary storage height

i = infiltration rate

k = coefficient of permeability of filter media

n = porosity of filter media

Qo = discharge rate of outflow

Q_{wq} = water quality discharge rate

RCS = Rate Control Standard

t = maximum drawdown time (48 hours)

t_f = design filter bed drain time

t_f = design filter bed drain time (days)

t_{RCS} = intended RCS detention time

t_{VCS} = intended VCS detention time

V = design volume for infiltration basin and underground infiltration system

VCS = volume control standard

Vf = water volume within filter bed

Vf_{temp} = temporary storage volume above the filter bed

Vs = volume within sediment chamber

V_T = design volume for infiltration trenches and dry wells

Vw = wet pool storage volume

V_w = design volume

w = particle settling velocity

III. Glossary

A – B – C – D – E – F – G – H – I – J – K – L – M – N – O – P – Q – R – S – T – U – V – W – XYZ

A

access and egress control — reinforced or rocked entrance and exit points to the site to deter tracking of sediment off the site onto adjacent streets

adsorption — the adhesion of an extremely thin layer of molecules to the surfaces of solid bodies or liquids with which they are in contact

aggrade — the build up of sediment or eroded material

anaerobic condition — operating in a system where there is the absence of free oxygen available for biologic use.

animal waste management — practices and procedures which prevent the movement of animal wastes or byproducts from feeding or holding areas into the wider environment.

annual load — quantity of pollutants, sediment, or nutrients carried by a water body over the period of a year

antecedent soil moisture — the water content held by a soil before a storm event. This has an effect on the amount of water that will runoff due to that event.

atmospheric controls — reducing or removing wind erosion, dust, or statutory emissions regulations

B

baffle weir — A structure used in measuring the rate of flow fitted with a grating or plate across a channel or pipe which makes the flow more uniform in different parts of the cross section of the stream.

bankfull — flow in a stream or river where the water level is to the top of its bank. This is considered to be the channel forming flow and has a recurrence interval of around 2.5–years.

bank stabilization — activities undertaken to shore up or ensure the integrity of a stream or river bank and protect it from erosion and slumping.

base flow — the flow coming from ground water inputs to a stream or river system

basin — a depression in the surface of the land that holds water

bed load — the sand, gravel or rocks which are transported along the stream bottom by traction, rolling, sliding or saltation

Best Management Practice (BMP) — one of many different structural or non–structural methods used to treat runoff, including such diverse measures as ponding, street sweeping, filtration through a rain garden and infiltration to a gravel trench.

better site design (BSD) — the application of non–structural practices at residential and commercial sites to reduce impervious cover, conserve natural areas, and use pervious areas to more effectively treat stormwater runoff.

biological additives products which are formulated with specialized bacteria, enzymes, or other living components that can be added to boost pollution treatment efficiencies, eg. chitosan

biological oxygen demand(BOD) a measure of the amount of oxygen required to biologically degrade organic matter in the water.

bioretention a soil and plant–based stormwater management best management practice (BMP) used to filter runoff

bounce water level fluctuations due to topography, soils, and runoff inputs during and after precipitation events.

buffers a vegetative setback between development and streams, lakes, and wetlands whose aim is to physically protect and separate the resource from future disturbance or encroachment.

C

catch basin an inlet to the storm drain system that typically includes a grate or curb inlet.

catch basin insert devices that attach to the entrance of a catch basin or mount inside the catch basin. They are designed to improve stormwater quality by either preventing debris and pollutants from entering the basin, or by retaining or treating the water in the basin.

channel protection actions taken to prevent habitat degradation and erosion that may cause downstream enlargement and incision in urban streams due to increased frequency of bankfull and sub–bankfull stormwater flows.

chemical controls includes such activities as salt management, fertilizer/pesticide management, and spill prevention and containment

chemical oxygen demand The quantity of oxygen used in biological and non–biological oxidation of materials in water; a measure of water quality.

chemical treatment removal of pollutant from the water column via chemical means, eg. Ferric chloride, alum, polyacrylamides

cistern a technique which captures and temporarily stores rooftop runoff at confined sites, gradually releasing it over pervious areas.

cluster design a reduction of average lot size within a residential development in exchange for greater conservation of natural areas.

coincident peaks upstream peak discharge arriving at the same time a downstream structure releases its peak discharge thus increasing the total discharge well above what it was on the pre-development hydrograph.

cold climate sizing sizing of stormwater practices to accommodate snowmelt. This is larger than rainfall–based criteria sizing in Minnesota since snowfall represents more than 10% of the annual precipitation.

computable pollutant a pollutant for which enough runoff concentration and BMP performance data is available to perform a site–based pollutant load calculation documenting no increase in loading.

conservation easement a restriction placed on a piece of property to protect the resources associated with the parcel. The easement is either voluntarily sold or donated by the landowner, and constitutes a legally binding agreement that prohibits certain types of development from taking place on the land.

construction sequencing	a specified work schedule that coordinates the timing of land–disturbing activities and the installation of erosion–protection and sedimentation–control measures
conveyance	a structure or feature used for transferring water from one location to another
curb and gutter system	edging along the side of streets meant to quickly convey stormwater runoff from the street and adjacent areas into the stormwater system
curve number	an index combining hydrologic soil group, land use factors, treatment, and hydrologic condition. Used in a method developed by the SCS to determine the approximate amount of runoff from a rainfall event in a particular area

D

dead storage	the permanent storage volume of a pond
degrade	downcutting where softer material is present in a stream channel
densimetric stratification	impairment of vertical mixing and oxygenation of bottom water layers
design storm	streamflow from a storm event used as a standard for which performance of stormwater management practices are measured.
detention time	the theoretical calculated time that a small amount of water is held in a settling basin.
disconnection	technique to spread runoff generated from rooftops or impervious surfaces into adjacent pervious areas where it can be filtered and infiltrated.
drainageway	a course or channel along which water moves in draining an area
dry pond	a water bearing stormwater management facility that controls peak runoff flows to receiving bodies such as rivers and streams which is typically free of water during dry periods, but filled during times of rainfall
dry well	a deep covered hole acting as an underground storage facility for stormwater until it seeps into the surrounding soil.

E

elution	washing out of ions in solution from a snowpack
erosion	the wearing down or washing away of the soil and land surface by the action of water, wind or ice
erosion control	any efforts to prevent the wearing or washing away of the soil or land surface
erosion control blanket	a natural or geotextile mat placed in areas susceptible to erosion to hold the soil in place until it can be permanently stabilized through vegetation or armoring
eutrophic	an environment which has an excessive concentration of nutrients
evaporation	the process of changing from a liquid state into a gas

evapotranspiration	loss of water to the atmosphere as a result of the joint processes of evaporation and transpiration through vegetation
event–based load	quantity of pollutants, sediment, or nutrients carried by a water body for particular magnitude storm events
exfiltration	uncontrolled outward leakage through cracks and interstices
extensive green roof	xeriscape type plantings in shallow, draughty growing medium typically on urban rooftops
extreme event	an 100–year, 24–hour rain event or an 100–year, 10–day snowmelt event or greater
extreme flood control	for the 100–year, 24–hour or larger events, to maintain the boundaries of the pre-development 100–year floodplain, reduce flooding risks to life, reduce property damage, and protect the physical integrity of the stormwater management practices.

F

fen	a peat accumulating wetland that receives some drainage from surrounding mineral soils and usually supports marsh–like vegetation. Richer in nutrients and less acidic than bogs due to ground water inflows.
ferrocyanide	an anti–caking additive to road salt; when converted to its free cyanide form (FCN) becomes extremely toxic to aquatic life
filter bed	a sand or gravel bottomed treatment used to filter stormwater
filtration	a series of processes that physically removes particles from water
first flush	the majority of pollutants carried in urban runoff are carried in the first ½" of runoff from a site
floodplain	land adjacent to a waterbody which is inundated when the discharge exceeds the conveyance capacity of the normal channel. Often defined in a regulatory sense as the extent of the 100–year flood.
flow control	controlling the rate and volume of water leaving a site
forebay	an extra storage space or small basin located near the inlet to settle out incoming sediments before water moves on into a pond or detention area
freeze–thaw cycle	the alternation between freezing and thawing in the snowpack. This cycle changes the composition and characteristics of the snowpack and can effect its pollutant carrying ability and the amount of runoff generated
frequency curve	A derivative of the probability curve that expresses the relation between the frequency distribution plot, with the magnitude of the variables on one axis and the number of occurrences of each magnitude in a given period as the other
frost heave	a phenomenon in cold areas in which water that is trapped in soil or cracks in rocks alternately freezes and thaws. This causes the water to expand and contract which can cause significant movement and upheaval of the soil or rock

G

geomorphology	the study of the form and development of the landscape

gleyed	a blue–gray, sticky, compacted soil, usually indicative of saturated conditions
global warming	the progressive gradual rise of the Earth's surface temperature thought to be caused by the greenhouse effect, which may be responsible for changes in global climate patterns
grade breaks	point where the ground slope changes
grass channels	a natural open channel conveyance system which is preferable to curb and gutter where development density, soils, and slopes permit
green roof	a rooftop treatment practice where a thin planting media is established on roof surfaces and then planted with hardy, low–growing vegetation
ground water	water occupying the sub–surface saturated zone
ground water mounding	the localized rise in water table or potentiometric surface caused by the addition or injection of water
gully erosion	the widening, deepening and head cutting of small channels and waterways (rills) due to erosion by water or snowmelt, typified by channels one foot or more deep

H

head	the difference in elevation between two points in a body of water and the resulting pressure of the fluid at the lower point
high density residential	a high concentration of housing units in a specific area or on a specific property, typical of urban areas
hotspot	point source potential pollution generating land uses such as gas stations, chemical storage facilities, industrial facilities, etc
housekeeping (BMP)	any of a number of BMPs designed to keep pollutants from entering the waste stream by maintaining clean conditions, including street sweeping, litter pick–up and animal clean–up
hydrograph	graphical representation of stage or discharge at a point in a drainage as a function of time
hydrologic soils groups	an NRCS designation to give different soil types to reflect their relative surface permeability and infiltrative capability. Rankings for from high infiltration rates in Group A to very low infiltration rates in Group D
hydrology	the science dealing with the properties, distribution, and circulation of water
hydroperiod	the length of time an area is inundated or saturated by water

I

impaired waters	streams or lakes that do not meet their designated uses because of excess pollutants or identified stressors
impervious surface	a surface in the landscape that impedes the infiltration of rainfall and results in an increased volume of surface runoff
infiltration	flow of water from the land surface into the subsurface
industrial materials or activities	include but are not limited to material handling equipment or activities, industrial machinery, raw materials, intermediate products, by-products, final products, or waste products

inlet protection	preservation of the integrity and protection from the erosion of the area where water enters into a treatment area usually by vegetation or armoring
intensity–duration–frequency curves (IDF)	graphical representation of the intensity, duration, and frequency of a differing rainfalls over time
intensive green roof	rooftop systems including earth-bermed structures which ar reliant on rich, deep substrates and may include shrubs or trees
interflow	water that travels laterally or horizontally through the aeration zone during or immediately after a precipitation event and discharges into a stream or other body of water
interstitial water	water in the pore spaces of soil or rock
isopluvial	line on a map along which an equal percentage of the total annual precipitation falls in a given season or month

J

K

L

Landlocked Basin	a basin that does not discharge under back-to-back 100-year, 24-hour rainfall events.
lattice blocks	a form of pervious pavers consisting of interlocking components having an open space in the middle for vegetation or gravel
live storage	the portion of a storage basin or reservoir that is at or above the outlet and used for temporary water storage
low density residential	a low concentration of housing units in a specific area or on a specific property, typical of rural areas
low impact development (LID)	the application of non–structural practices at residential and commercial sites to reduce impervious cover, conserve natural areas, and use pervious areas to more effectively treat stormwater runoff

M

media filters	filtration of stormwater through a variety of different filtering materials whose purpose is to remove pollution from runoff
medium density residential	a moderate concentration of housing units in a specific area or on a specific property, typical of suburban areas
mesotrophic	waters containing an intermediate level of nutrients and biological production
micropool	similar to wet ponds except there is a small micropool at the outlet to prevent resuspention of previously settled materials and prevents clogging of low–flow orifice
mobilization	the release and movement of bound chemicals, nutrients, or pollutants into the environment
mottled	soil marked with irregular brown and gray/black colors indicative of poor drainage and routine saturation cycles

municipal separate storm sewer systems (MS4) — A municipal separate storm sewer system is a conveyance or system of conveyances, owned or operated by a state, city, town, county, district, association, or other public body having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes that discharges to waters of the United States. There are three categories of regulated small MS4s: mandatory, discretionary and petition. MS4s are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP which must cover six minimum control measures and identify best management practices (BMPs) and measurable goals associated with each of these minimum control measures.

N

native vegetation — plants that are adapted to and occur naturally in a specific location

natural area conservation — the identification and protection of natural resources and features that maintain the pre-development hydrology at a site by reducing runoff, promoting infiltration, and preventing soil erosion.

no exposure — all industrial materials or activities are protected by a storm resistant shelter to prevent exposure to rain, snow, snowmelt, or runoff

Noncomputable pollutant — a pollutant for which there is not enough runoff concentration and BMP performance data available to perform a site–based pollutant load calculation documenting no increase in loading

nonpoint source pollution — pollution that enters a water body from diffuse origins on the watershed and does not result from discernable, confined, or discrete conveyances

O

orifice — outlet

overbank flood protection — prevention of flood damage to conveyance systems and infrastructure and reduction of minor flooding caused by an increased frequency and magnitude of floods exceeding the bankful capacity of a channel and spilling out over the floodplain.

P

peak flow control — controlling the timing and magnitude of the largest flow either leaving the site or flowing through the watershed utilizing stormwater management techniques to avoid flooding and damage downstream.

perimeter control — activities or practices designed to contain sediments on a project site

permanent storage pool — the volume in a pond or reservoir below the lowest outlet level, designed for water quality purposes to settle out particles and nutrients

permeable paver — a range of products that enable some fraction of rainfall to be infiltrated into a sub–base underneath the paver

pollution load — the product of flow volume times pollutant concentration

pollution prevention practices pro–active activities and strategies instituted to avoid introducing pollution into the environment

pollutograph graphical representation of pollution at a point in a drainage as a function of time

pre–treatment processes used to reduce, eliminate, or alter pollutants before they are discharged into publicly owned sewage treatment systems

primary treatment the first stage of wastewater treatment, including removal of floating debris and solids by screening, skimming and sedimentation

proprietary devices stormwater treatment devices which are privately developed and owned

Q

quiescent periods periods of rest or inactivity

R

rain barrel a container used to collect and store rainwater that is usually placed below the downspout of a roof gutter. The collected water is used to water the landscape

rainfall distribution describes how the rain fell in a 24–hour period, ie. whether the precipitation occurred over a 1–hour period or over the entire 24–hour period

rainfall frequency spectrum describes the average frequency of the depth of precipitation events (adjusted for snowfall) that occur during a normal year

rain garden a landscaping feature that is planted with native perennial plants and is used to manage stormwater runoff from impervious surfaces such as roofs, sidewalks, and parking lots

rate control controlling the rate that stormwater is released from localized holding areas into larger conveyance systems

receiving water a body of water such as a stream, river, lake, or ocean, which receives stormwater and wastewater

recessional limb the portion of the hydrograph after the peak where flows are returning to lower or baseflow levels

recharge the addition of water to an aquifer by natural infiltration or artificial means

recurrence interval the inverse probability that a certain flow will occur. It represents a mean time interval based on the distribution of flows over a period of record

redevelopment any construction, alteration, or improvement that disturbs greater than or equal to 5,000 square feet of existing impervious cover performed on sites where the existing land use is commercial, industrial, institutional, or residential

removal rate the rate at which a pollutant is removed from the water column

retention the permanent or temporary storage of stormwater to prevent it from leaving the development site

retrofit	the introduction of a new or improved stormwater management element where it either never existed or did not operate effectively
return interval	the inverse probability that a certain flow will occur. It represents a mean time interval based on the distribution of flows over a period of record
rill erosion	an erosion process in which numerous small channels several inches deep are formed
riparian areas	areas adjacent to a water body acting as transition zones between terrestrial and aquatic systems
riser	a vertical assembly of pipe and fittings that generally distributes water upward
roof leader	a downspout or other conveyance for runoff that has been collected from roof tops routing stormwater down to the ground surface or to a sewer service
rooftop runoff storage	installation of practices to capture and temporarily store rooftop runoff at confined sites and gradually release it over pervious areas for use for irrigation
runoff	the portion of rainfall or snowmelt not immediately absorbed into the soil that drains or flows off the land and becomes surface flow
runoff volume minimization	reducing as much as possible the amount of water running off surfaces or leaving a site
runoff management	techniques, practices and strategies for dealing with runoff and minimizing its impact to the greater environment

S

secondary treatment	biological and mechanical processes that remove dissolved or suspended material from wastewater
sediment	any particulate matter that can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed or bottom of a body of water
sediment control basins	a designed depression in the landscape utilized to settle out sediments from the water column before discharge into other drainages
sediment removal	the removal, usually by settling or filtering, of suspended sediments from the water column
sediment yield	The amount of sediment removed from a watershed over a specified period of time
settling	a technique to remove sediment from wastewater by slowing the water flow velocity allowing the sediments to sink to the bottom
silt curtain	a natural or synthetic fabric suspended by floats and weighted at the bottom which is stretched across a water feature and used to trap and retain sediments on site
silt fence	fence constructed of wood or steel supports and either natural (eg burlap) or synthetic fabric stretched across an area of non–concentrated flow during site development to trap and retain on–site sediment due to rainfall runoff

site constraints	conditions unique to the site that that serve to restrain, restrict, or prevent the implementation of proposed or desired design features
site reforestation	reforestation of existing turf or barren ground at the development site with the explicit goal of establishing a mature forest canopy or prairie condition that intercepts rainfall, and maximizes infiltration and evapotranspiration
skimmer	device used to take up or remove floating matter from the water's surface
slope stabilization	activities or techniques employed to maintain the integrity or stop the degradation of sloped areas
small storm hydrology	a less than 10–year event
snowmelt	the sudden release of accumulated snow and ice with the advent of warm weather
snowpack	a horizontally layered accumulation of snow from snowfall events which accumulates and persists through the winter and may be modified by meteorological conditions over time
soakaway pit	small, excavated pits, backfilled with aggregate, used to infiltrate good quality stormwater runoff, such as uncontaminated roof runoff
soil amendment	tilling and composting of new lawns and open spaces within a development site to recover soil porosity, bulk density, and reduce runoff
sorbent	material which extracts one or more materials from the water via absorption or adsorption
source water protection area	an identified area with restricted or modified land use practices designed to protect the public drinking water supply from the introduction of contaminants
spring snowmelt event	large amount of melting of the winter's accumulated snow over a short period of time (~2 weeks). Large flow volumes typical and may be the critical water quality design event
standpipe	a vertical pipe or reservoir for water used to secure a uniform pressure
stage	the height of a water surface above an established reference point
storm distribution	a measure of how the intensity of rainfall varies over a given period of time
stormwater	water that is generated by rainfall or snowmelt which causes runoff and is often routed into drain systems for treatment or conveyence
stormwater credits	activities that can be undertaken in order to reduce the sizing or requirements for stormwater management at a site
stormwater planter	self–contained landscaping areas which capture and temporarily store a fraction of rooftop runoff and filter it through the soil media

stormwater pollution prevention plan (SWPPP)	a plan for preventing or minimizing pollution generated at construction sites
stormwater pollution prevention program (SWPPP)	a program that is required to be developed by MS4 communities to incorporate applicable best management practices, measureable goals and which must include the six minimum control measures
stormwater treatment train	a suite of stormwater management practices incorporating aspects of pollution prevention, volume control and water quality controls
streambank stabilization	activities or techniques employed to maintain the integrity or stop the degradation of streambanks due to erosion and sedimentation
sublimation	the process of transforming from a solid directly into a gas without passing through a liquid phase
subwatershed	a subdivision based on hydrology corresponding to a smaller drainage area within a larger watershed
swale	a wide, shallow, vegetated depression in the ground designed to channel drainage of water

T

Technical Publication 40 (TP–40)	U.S. Weather Bureau publication that is the standard reference for frequency analysis in Minnesota
Technical Release Number 20 (TR–20)	a single–event rainfall–runoff computer model developed by the U.S. Soil Conservation Service in 1964.
Technical Release Number 55 (TR–55)	a simplified procedure to calculate storm runoff, volume, peak rate of discharge, hydrographs and storage volumes developed by the U.S. Natural Resource Conservation Service in 1975
temporary construction sediment control techniques	practices employed on an active construction site to control movement of sediment within or off of the site until permanent vegetation or sediment controls can be established
thermal impact	the impact to streams and water bodies of stormwater runoff addition which are higher in temperature than the ambient stream or water body temperature. This causes stress or may result in the death of temperature–sensitive organisms such as trout
thermal protection	techniques and practices such as infiltration and shading which act to preserve and protect the ambient temperatures of streams and waterbodies from temperature–raising effects of stormwater runoff
total maximum daily load (TMDL)	the amount of a pollutant from both point and nonpoint sources that a waterbody can receive and still meet water quality standards
total phosphorus (TP)	a nutrient that can also be a contaminant because of its use by nuisance algae
total suspended solids (TSS)	a measure of the amount of particulate material in suspension in a water column

transpiration	the passage of water vapor into the atmosphere through the vascular system of plants
trash rack	a structural device used to prevent debris from entering a pipe spillway or other hydraulic structure
treatment	any method, technique, or practice used for management purposes
trench	a long steep–sided depression in the ground used for drainage or infiltration
turbidity	the cloudy appearance of water caused by the presence of suspended and colloidal matter

U

under drain	An underground drain or trench with openings through which the water may percolate from the soil or ground above
unified sizing criteria	statewide criteria for the sizing of stormwater management systems

V

vegetative filters	the removal of sediment, nutrients, or pollutants by plant structures
volume control	controlling the overall volume or amount of stormwater that is released from a site or localized holding area into the larger conveyance system

W

water balance	A hydrological formula used by scientists and land managers to determine water surpluses and deficits in a given area. Includes inputs such as precipitation; outputs such as evapotranspiration, infiltration, and runoff; and storage within the system
water quality sizing	tied to the volume of stormwater runoff
water quality volume	the permanent pool in a water detention pond
watershed	a topographically defined area within which all water drains to a particular point
weir	a spillover dam–like device used to measure or control water flow
wellhead protection area	an identified area with restricted or modified land use practices designed to protect the well supply area from the introduction of contaminants
wetland	land that is transitional between aquatic and terrestrial ecosystems and must: have a predominance of hydric soils, be inundated or saturated by surface water or ground water at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, and under normal circumstances support a prevalence of hydrophytic vegetation. To be a wetland the area must meet wetland criteria for soils, vegetation, and hydrology as outlined in the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual.
wetland systems	hydrologically interconnected series of wetlands which includes the interrelatedness of habitat, wetland functions, and biology

wet pond a permanent pool of water for treating incoming stormwater runoff

wet vault A wet vault is a vault stormwater management device with a permanent water pool, generally 3 to 5 feet deep

XYZ

INVER GROVE HEIGHTS
Northwest Area

Appendix D

Contacts, Submittal Materials, Inspections, Operations and Maintenance

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Contacts, Submittal Materials, Inspections, Operations and Maintenance

Appendix D

this appendix contains a number of materials that may be useful to manual users in identifying key people and information needed from the project development phase, through development of the site and follow up inspections

Contents

I. Contacts..... 3
II. Submittals..... 5
III. Construction Inspection Checklists..... 33
IV. Operations and Maintenance..... 54

I. Contacts

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sthureen@ci.inver-grove-heights.mn.us

Gary Johnson
Public Works Director
Inver Grove Heights
8150 Barbara Ave.,
Inver Grove Heights, MN 55077
(651)450-2571
gjohnson@ci.inver-grove-heights.mn.us

Tom Link
Community Development Director
Inver Grove Heights
8150 Barbara Ave.,
Inver Grove Heights, MN 55077
(651)450-2546
tlink@ci.inver-grove-heights.mn.us

Allan Hunting
Inver Grove Heights
8150 Barbara Ave.,
Inver Grove Heights, MN 55077
(651)450-2554
ahunting@ci.inver-grove-heights.mn.us

Weblinks

IGH Northwest Area: http://www.ci.inver-grove-heights.mn.us/dev/nwarea.html
IGH Community Development: http://www.ci.inver-grove-heights.mn.us/dev/index.html

Gun Club Lake WMO

Eric Macbeth
Administrator
Gun Club Lake Water Management Organization
3501 Coachman Point
Eagan, MN 55122
Phone: (651) 675-5300
Fax: (651) 675-5360
gclwmo@cityofeagan.com

Lower Mississippi River WMO

Gary Johnson
Inver Grove Heights Representative
Lower Mississippi River WMO
8150 Barbara Ave.,
Inver Grove Heights, MN 55077
(651)450-2571
gjohnson@ci.inver-grove-heights.mn.us

Web Links

Gun Club Lake WMO: http://www.dakotacountyswcd.org/watersheds/gunclubwmo/
Lower Mississippi River WMO: http://www.dakotacountyswcd.org/watersheds/lmrwmo/lr-news2005.pdf

Local Government Unit for the Wetland Conservation Act (LGU)

Allan Hunting
Inver Grove Heights
8150 Barbara Ave.,
Inver Grove Heights, MN 55077
(651)450-2554
ahunting@ci.inver-grove-heights.mn.us

Dakota County Soil and Water Conservation District

Laura Jester
Dakota County Watershed Conservationist
Dakota County Soil and Water Conservation District
4100 220th Street West, Suite 102
Farmington, MN 55204
laura.jester@co.dakota.mn.us

Mike Isensee
MPCA Stormwater Program for Construction Activities Inspections Contact
Dakota County Soil and Water Conservation District
4100 220th Street West, Suite 102
Farmington, MN 55204
651-480-7781
mike.isensee@co.dakota.mn.us

Web Link

http://www.dakotacountyswcd.org/

Minnesota Board of Soil and Water Resources (BWSR)

Less Lemm
Board Conservationist
BWSR
520 Lafayette Rd. N.
St. Paul, MN 55155
(651) 296-6057
les.lemm@bwsr.state.mn.us
http://www.bwsr.state.mn.us/

Minnesota Department of Natural Resources (DNR)

Pat Lynch
DNR Area Hydrologist
DNR Waters
Central Region
1200 Warner Rd.
St. Paul, MN 55106
651-772-7917
pat.lynch@state.mn.us
http://www.dnr.state.mn.us/waters/index.html

Minnesota Department of Transportation (Mn/DOT)

Nicklas Tiedeken
Water and Wetland Requirement Compliance
Office of Environmental Service
Mn/DOT
395 John Ireland Blvd
Mail Stop 620
St Paul, MN 55155-1899
(651) 284-3789
nicklas.tiedeken@dot.state.mn.us
http://www.dot.state.mn.us/environment/

Minnesota Pollution Control Agency (MPCA)

Brian Gove
MPCA Stormwater Program for Construction Activities Technical Contact
520 Lafayette Rd. N.
St. Paul, MN 55155651-296-7036
brian.gove@pca.state.mn.us
http://www.pca.state.mn.us/water/stormwater/

United States Army Corps of Engineers (USACOE)

Brad Johnson
Corps of Engineers Permit Staff
Department of the Army
St. Paul District, Attn: OP-R
190 Fifth Street East, Suite 401
St. Paul, MN 55101-1638
651-290-5250
brad.a.johnson@mvp02.usace.army.mil
http://www.mvp.usace.army.mil/regulatory/

II. Submittals

Examples of forms and instructions for typical submittal requirements for development projects are provided below. These materials include:

- ► Land alteration requirements [pages 7–11]
- ► Sample building permit application [page 12]
- ► Sample final plat application [pages 13-16]

- Sample planning application form [pages 17-21]
- Sample land alteration application [pages 22-24]
- Sample petition for local improvement[page 25]
- Sample preliminary plat application [pages 26-29]
- Minnesota Developer Checklist [page 31]
- 2004 Joint Trench contact - Metro East-Xcel Energy [pages 32]
- New Plat Submittal Form / New Residential Development [pages 33]

For more information on required submittals, contact Allan Hunting, the City Planner for the City of Inver Grove Heights.

CITY OF INVER GROVE HEIGHTS

DAKOTA COUNTY, MINNESOTA

LAND ALTERATION REQUIREMENTS FOR ALL CONSTRUCTION

As per Section 420 of the Inver Grove Heights City Code, the following requirements will be enforced:

1. All slopes must be a minimum of four (4) feet horizontal to one (1) foot vertical.

2. No land may be altered that results in water runoff causing flooding or erosion on adjacent property. Such runoff shall be channeled to an appropriate drainage facility.

3. No concrete, asphalt, tree stumps or branches or demolition debris (as defined in City Code, Section 420.19) shall be use as fill material.

4. Operating hours: 7:00 a.m. to 7:00 p.m. only.

5. Fencing: When open excavation exceeds 20 feet and/or slope of 2:1, or greater, a fence completely around the site is required.

6. No stagnant water is permitted to collect.

7. All affected areas are to have topsoil re-spread and turf re-established within six (6) months of occupancy, or as defined by terms of a land alteration permit.

8. All excavation and filling work associated with a building permit is to be completed within six (6) months of occupancy. All work done after this time requires a permit as prescribed by Section 420 of the City Code.

DAKOTA COUNTY SOLID WASTE REGULATION
QUALIFIED CLEAN FILL GUIDELINES

Pursuant to Dakota County Ordinance No. 110, Solid Waste Management, Section VII., Subsection 1., the Dakota County Environmental Management Department ("Department") is granted the authority to waive provisions of Ordinance No. 110 pertaining to demolition landfills or special waste facilities. The intent and purpose of these guidelines are : (1) to allow for the use of certain solid waste materials as fill for beneficial land use project where the potential for environmental, public health and safety problems are minimal, and (2) to establish a staff review and approval process for qualified clean-fill projects which will not be subject to County Board licensure.

I. DEFINITIONS.

A. "Clean Fill." Uncontaminated natural earthen materials such as soil, sand and gravel.

B. "Demolition Waste." Waste resulting from the demolition of man-made structures and other similar materials specifically approved by the Department. This excludes asbestos and other materials specifically prohibited by the Department.

C. "Inert." Lacking the physical or chemical capacity to adversely impact human health or the environment.

D. "Qualified Clean Fill." Uncontaminated concrete, brick, or inert materials as approved by the Department.

E. "Qualified Clean Fill Landfill." Utilization of qualified clean fill for a beneficial land use project.

II. LOCATION REQUIREMENTS.

Qualified clean fill projects shall not be located within the following areas:

A. Within areas that violate local land use and zoning laws.

B. Within locations which may adversely impact surface water drainage.

C. Within standing water, a wetland, lake, pond, reservoir, stream, or river, unless specifically approved by governing agencies for purposes of bank stabilization/erosion prevention. If so, attach a copy of the approval letter.

D. Within areas where there are karst features, such as sinkholes, solution channels, disappearing streams, or caves.

E. Within areas which may adversely impact public health and safety or the environment as determined by the Department.

III. **DIMENSION REQUIREMENTS.** Aggregate size may **NOT** exceed eighteen (18) inches in any dimension unless specifically approved by the Department.

IV. **APPLICATION REQUIREMENTS.** The responsible party (owner/operator) shall submit to the Department a narrative project description, including:

A. The names, addresses and telephone numbers of the property owner(s) and the contractor(s) or party(ies) proposing to conduct the actual fill operation.

B. A legal description of the property at which filling activities are proposed.

C. The address/location from which fill materials originate.

D. A description of the proposed fill material(s) including: quantity, the fill type (i.e., concrete, brick) and the physical/chemical characteristics of the fill material (i.e., aggregate size). Chemical analysis of proposed fill materials may be required.

E. Plans and specifications for the proposed fill site, including at a minimum scale drawing or map indicating fill area(s), property lines, public road and access roads, surface water bodies, existing structures, north arrow, and other information as required by the Department.

F. The projected timetable for the proposed fill project.

G. A description of any local, state, and/or federal licenses, permits, approvals needed/acquired. If not applicable, please indicate. Provide copies of required applications made and approvals received from local, regional and/or state authorities.

H. Reapplication will be required if the project exceeds the volume or duration standards indicated in Section VII.

I. Provide a statement describing the reason for the fill project, and the expected use of the property after completion.

V. **INSPECTION REQUIREMENTS.** The Department requires and shall implement the following inspections prior to and in conjunction with a qualified clean fill project.

A. Inspection of the proposed fill material and the site from which it originates, prior to its removal.

B. Inspection of the proposed fill site prior to placement of any fill.

C. The responsible party(ies) shall notify the Department at least three (3) days prior to placement of fill at the fill site, once Department approval has been obtained.

D. The Department reserves the right to inspect the fill project at any time.

E. The Department shall conduct a final inspection of the fill site upon completion of the project, and reserves the right to require additional work at the fill site if proper site closure has not occurred.

VI. CLOSURE REQUIREMENTS. The following closure requirements shall be implemented by the responsible party(ies).

A. The Department form, "Closure Record Location of an Abandoned Disposal Site," shall be filed on the property deed with the Dakota County Registrar of Deeds.

B. Completed fill areas shall be covered with earthen material or otherwise terminated properly, in accordance with the plans and specifications submitted to and approved by the Department.

C. Measure shall be taken to minimize erosion, such as the establishment of vegetation, and provision of adequate surface water drainage.

VII. VOLUME REQUIREMENT AND CLASSIFICATION LEVELS. The volume of fill material(s) allowed by the Department to be deposited at any one location shall be determined on a case-by-case basis, dependent upon location factors and type of material(s).

Amount of Fill	Duration of Project
A. Less than 100 cubic yards (exempt from County review/approval)	Less than 30 days
B. 100 - 500 cubic yards (Level I)	Less than 90 days
C. 500 - 5,000 cubic yards (Level II)	Less than 1 year
D. More than 5,000 cubic yards (Level III)	Less than 2 years

If a project exceeds either the volume or the duration, the Department will require reapplication by the responsible party(ies) and the project will be reclassified to a higher level, unless the project already exceeds 5,000 cubic yards, in which case, the project will continue to be classified at the greater than 5,000 cubic yard level.

VIII. PERFORMANCE BOND. Bonds or letters of credit shall be required for project classification levels, as referenced in Section VII. above, in the following amounts:

Level I — $5,000
Level II — $10,000
Level III — $20,000

Insurance amounts, for general liability and vehicle liability for project operations, shall be in accordance with the amounts and conditions specified in Dakota County Ordinance No. 110, Section II., Subsection 5.

IX. FEES. To be determined per classification by the County Board of Commissioners on an annual basis.

X. APPEAL. Any party determined by staff to be subject to these guidelines shall have the right to appeal that determination or any subsequent determinations made by staff during the project review process to the County Board.

SWM:cleanfil

CITY OF INVER GROVE HEIGHTS
BUILDING PERMIT APPLICATION

PERMIT #

SITE ADDRESS

1. _____
BUILDING SITE ADDRESS ZIP CODE

2. _____
OWNER NAME ADDRESS PHONE (HOME) (WORK)

3. _____
CONTRACTOR ADDRESS PHONE (FAX)

4. _____
ARCHITECT/ENGINEER ADDRESS PHONE (FAX)

5. _____
LEGAL DESCRIPTION OF SITE (attach if long description)

6. CLASS OF WORK: NEW ☐ ADDITION ☐ REMODEL/ALTERATION ☐ OTHER ☐

7. DESCRIBE WORK _____

_____

8. USE OF BUILDING _____

9. CONSTRUCTION DATA:

Setbacks: Front _____ Square Feet: Basement _____ Garage _____
Right Side _____ 1st Floor _____ Porch _____
Left Side _____ 2nd Floor _____ Deck _____
Rear Side _____ 3rd Floor _____ Other _____

Structure Height: _____ VALUATION (Incl. Labor): _____

10. The undersigned acknowledges that he/she has read this application and that the above is correct and agrees to comply with all the ordinances and laws of the City of Inver Grove Heights regulating building construction.

_____ _____
SIGNATURE OF CONTRACTOR OR AUTHORIZED AGENT DATE

NOTICE: This is an application only. Permit will be issued after city approval and payment of fees.

OFFICE USE ONLY

		FEE TYPE	AMOUNT	RECEIPT CODE
Zoning	_____	Contractors License	_____	AK
Occupancy	_____	Building Permit	_____	AL
Type of Constr.	_____	Plan Review	_____	AM
# of Stories	_____	Surcharge	_____	BR
Bdrm/Dwelling Units	_____	Sprinkler/Alarm Permit	_____	AO
Max. Occup. Load	_____	Misc. Permits (Sign, Fence)	_____	AR
Sprinklered	_____	MCWS Sac Charge	_____	BP
		Sewer Connection Fee	_____	BD
Application Accepted By	_____	Water Connection Fee	_____	BC
License No.	_____	Water Treatment Fee	_____	CD
Building Insp. Approval	_____	Meter Sale	_____	WD
Planning Approval	_____	Tax on Meter	_____	BQ
Engineering Approval	_____	B-Line Sewer Connection	_____	BE
Fire Marshal Approval	_____	Park Dedication Fees	_____	BO
Approved to Issue By	_____	Eagan Utility Connections	_____	CA
Date Approved	_____	Other Forms & Fees	_____	AS
		TOTAL FEE	_____	

Receipt # _____ Date Issued _____

SPECIAL CONDITIONS _____

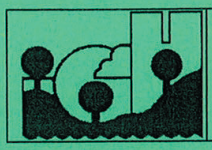
_____

_____

★ APPLICANT NOT TO SEPARATE SHEETS ★

NOTICE: Inspections made by the City are a public service and do not constitute any representation, guarantee or warranty, either implied or expressed, to any person as to the condition of the building inspected.

8150 Barbara Ave. • Inver Grove Heights, MN 55077 • Inspections 651-450-2550



FINAL PLATS

PETITIONER'S INSTRUCTIONS

ALL REQUESTS FOR FINAL PLATS SHALL BE FILED WITH THE CITY'S PLANNING DIVISION. THE FOLLOWING DOCUMENTATION SHALL ACCOMPANY ALL REQUESTS BEFORE A REQUEST IS ACCEPTED FOR PROCESSING.

1. A completed application form with fees and including all information listed below.

2. Submit thirteen (13) folded full size copies plus one set of 11 x 17 reductions of the following:

   a) Final Plat; Prepared for recording purposes in accordance with provisions of Minnesota State Statutes and Dakota County regulations. The final plat shall contain the following information:

      - Name of the subdivision, which shall not duplicate or too closely approximate the name of any existing subdivision.

      - Location by section, township, range, county and state, and including descriptive boundaries of the subdivision, based on an accurate traverse, giving angular and linear dimensions which must mathematically close. The allowable error closure of any portion of a final plat shall be one foot (1') in seven thousand five hundred feet (7500').

      - The location of monuments shall be shown and described on the final plat. Locations of such monuments shall be shown in reference to existing official monuments on the nearest established street lines, including true angles and distances to such reference points or monuments.

      - Location of lots, streets, public highways, alleys, parks and other features, with accurate dimensions in feet and decimals of feet, with the length of radii and/or arcs of all curves, and with all other information necessary to reproduce the plat on the ground shall be shown. Dimensions shall be shown from all angle points of curve to lot lines.

      - Lots shall be numbered clearly. Blocks are to be numbered with numbers shown clearly in the center of the block.

- The exact locations, widths and names of all streets to be dedicated.
- Location and width of all easements to be dedicated.
- Name and address of surveyor making the plat.
- Scale of plat (the scale to be shown graphically on a bar scale), date and north arrow.
- Statement dedicating all easements as follows:
  Easements for installation and maintenance of utilities and drainage facilities are reserved over, under, and along the strips marked "utility easements".
- Statement dedicating all streets, alleys and other public areas not previously dedicated as follows:
- Streets, alleys and other public areas shown on this plat and not heretofore dedicated to public use are hereby so dedicated.

b) Certification Requirement:

- Certification by registered surveyor in the form required by Section 505.03, Minnesota Statutes, as amended.
- Execution of all owners of any interest in the land and any holders of a mortgage thereon of the certificates required by Section 505.03, Minnesota Statutes, as amended and which certificate shall include a dedication of the utility easements and other public areas in such form as approved by the City Council.
- Space for certificates of approval and review to be filled in by the signatures of the Chair of the City Planning Commission and the Mayor and Deputy City Clerk.

c) Utility Plan

Plan and profile showing existing utilities, proposed utilities, connection with existing utilities (watermain, sanitary sewer, storm sewer) appropriate easements as required.

Note whether utilities will be publicly or privately constructed, owned and maintained.

For plats in the unsewerd portion of the City, note drainfield locations on proposed lots. (Must be located on undisturbed soil.)

d) Street Plan

Plan and profile showing internal roads, grades, lengths of cul-de-sacs, curb data (horizontal and vertical), connection to existing streets or platted right-of-way, provisions for future extensions or connections to adjacent land, appropriate easements or right-of-way.

e) Street Signage Plan

Plan showing location and details for all street signage. This must include all street name signs, regulatory signs, and warning signs that are to be located within any public or private street right-of-ways associated with the project. The street signage plan does not include fire lane signage, which will be addressed by the Fire Marshal together with issuance of building permits.

f) Wetland Plan

Plan showing fill or draining of any wetland including sequencing justification and proposed mitigation consistent with the Wetland Conservation Act. All wetlands must be delineated in accordance with the Wetland Conservation Act.

g) Tree Preservation Plan

Plan showing location, size and specie of all significant trees (8 caliper inches or greater for deciduous trees, 10 feet in height for coniferous trees) including trees to be preserved, removed and those within 30 feet of grading limits.

h) Reforestation or Landscape Plan

Plan showing reforestation required by City Code Section 515.90. Subd. 28 and landscaping required by City Code Section 515.90. Subd. 10. Plan must identify location, size, species and quantity of plant materials.

i) Letter from Dakota County or MN/DOT

Containing recommendations on access or right-of-way requirements, if the property abuts county or state roads or right-of-way, or proposes access to a state or county road.

Other Possible Agency Reviews

- MN/DOT - When a proposed plat is adjacent to state right-of-way or road, or access to a state road is proposed.
- Dakota County - When a proposed plat is adjacent to a county right-of-way or road, or access to a county road is proposed.
- DNR - For subdivisions, Planned Unit Developments in a Shoreland Overlay Zone, or for variances requested from the Shoreland Management standards.
- U.S. Army Corps of Engineers - Permits are required for fills exceeding one acre in identified wetlands.
- EQB (Minnesota Environmental Quality Board) - Projects requiring environmental review.



CITY OF INVER GROVE HEIGHTS
8150 Barbara Avenue • Inver Grove Heights, MN 55077 •(651) 450-2545

PLANNING APPLICATION FORM

Section I: Applicant Information

Applicant's Name _____
Street Address _____
City/State/Zip _____
Mailing Address (if different than above) _____
Telephone Number (Home)_____(Work)_____(Fax)_____
E-Mail _____

Owner's Name (if different than above)_____
Street Address _____
City/State/Zip _____
Telephone Number (Home)_____(Work)_____(Fax)_____
E-Mail _____

Section II: Type of Application

___ Variance
___ Rezoning
___ Comp Plan Amendment
___ Waiver Of Plat
___ Conditional Use Permit
___ Preliminary Plat
___ Final Plat
___ Other: _____
___ Major Site Plan Review
___ Planned Unit Development
___ Zoning Code Amendment

Section III: Property Information

Property Address _____
Legal Description _____
_____
County Tax PIN _____

Section IV: Other Information

Attach the written description, plans and other required documents (See Petitioner's Instructions.).

APPLICANT SIGNATURE _____

OWNER SIGNATURE _____

SECTION V (Office Use Only):

Case Number:	_____	Plan Review Committee Date:	_____
Date Accepted:	_____	Planning Commission Date:	_____
Accepted By:	_____	Park & Rec. Commission Date:	_____
Receipt #:	_____	Environmental Commission Date:	_____
Escrow #:	702-0000-_____	City Council Date:	_____
		60 Day Deadline:	_____

Section VI: **Application Fees**

Request Type	Base Fee	GIS Fee	Escrow*	Total
Comprehensive Plan Amendment	$400	$ 50	$2,500	
Comprehensive Plan Amendment - Minor	$200		$250	
Zoning Code Amendment	$200	--	$500	
Zoning Code Amendment - Minor	$100		$250	
Rezoning	$400	$ 50	--	
Planned Unit Development (PUD)	$500 + plat fees	variable	$4,500	
PUD Amendment	$250		$1,000	
Preliminary Plat	$250 + $5/lot	--	$2,500	
Final Plat - Single Family Residential.	$200	$ 25/lot	$500	
Final Plat – Other (i.e. Commercial or Industrial)	$200	$100/acre	$2,500	
Waiver of Plat	$200	$ 25	--	
Administrative Subdivision	$100	$ 25/lot	--	
Conditional Use Permit - Single Family Residence	$250	--	--	
Conditional Use Permit - other	$300	--	$1,250	
Conditional Use Permit - other - Amendment	$150		$500	
Major Site Plan Review	$300		$1,000	
Variance - Residential	$150	--	--	
Variance - Commercial	$150	--	--	
Determination of Substantially Similar Use	$150		$200	
Street/Easement Vacation	$150	$ 50	--	
Street Dedication	$150	$ 50	--	
Wetland Conservation Act Certification	$ 75	--	--	
Wetland Replacement Plan	$200	$100/acre	$2,500	
TOTAL CUMULATIVE FEE	$ (Code "AV")	$ (Code "CB")	$ (Acct. #)	$

*The above escrow amounts represent the minimum deposit required. Additional escrow amounts may be required depending upon the size, complexity and scope of project.



CITY OF INVER GROVE HEIGHTS
8150 Barbara Avenue • Inver Grove Heights, MN 55077 •(651) 450-2545

Dear Applicant:

As outlined in the Planning Application Form, the City of Inver Grove Heights requires a cash escrow deposit to cover all costs directly related to processing your application. These costs include City staff time, administrative costs, and costs for any consultants essential to complete the application's review.

The City makes every effort to minimize the cost of reviewing your application. To be most effective at this, it is important that you submit complete documents, plans, and designs. Incomplete submittals typically result in increased review time, and may require more of the City's consultants to become involved in the review. For example, if the City Attorney is required to draft legal documents that your attorney could draft, your escrow account would have to cover the City Attorney's time. Your own attorney may be able to complete the documents less expensively. The City's legal firm currently bills $155/hour for its attorneys' time and $75/hour for its legal assistants' time.

If your escrow deposit is depleted before the application is concluded, you will be required to make an additional deposit. In all cases, any negative balance in your escrow account will need to be paid prior to releasing City approvals of your application. Excess escrow will be refunded to you after final action is taken by the City Council and all billings are posted to your account.

Please contact the City Planner at 651-450-2553 if there are unanswered questions or you are unsure how to proceed.

Sincerely,

CITY OF INVER GROVE HEIGHTS

Acknowledgement by applicant that this letter has been read and understood:

_____ _____
(Applicant's signature) (date)

CITY OF INVER GROVE HEIGHTS, MINNESOTA
PLANNING DIVISION

PROPERTY ACCESS CONSENT FORM

This is to certify that on _____, 20_____, I, _____, owner of property described as follows (address or legal description):

_____

_____

_____

_____

_____

_____, filed a request, (or authorized, by my signature, the filing of a request) with the Inver Grove Heights Planning Division for _____ on the described property. By filing the above referenced request, I hereby consent to permit access to said property, at any reasonable time, to members of City Staff, the Planning Commission, and the City Council for purposes of viewing the site and information gathering that is pertinent to the request.

_____ Dated: _____
Property Owner

(Please return this completed form to the Planning Division at the time of application for your planning request. If the Consent Form is not returned with your Planning Application Form, it will be assumed that you do not wish to grant access to your property for the stated purpose. A copy of the Consent Form will be retained in the planning file relative to your case. The consent granted by virtue of this form expires upon final City Council action relative to your request.)

OFFICE USE ONLY

Case No:_____ Applicant:_____

Planning Application Cycles (Year 2005)

To use this table, identify the application deadline in the far left column and follow the table to the right to determine the applicable meeting dates for your application.

***The Planning Division reserves the right to impose earlier application deadlines should the need arise to limit the length of upcoming agendas.*

Application Deadline	Plan Review Committee	Planning Commission	Park and Rec. Commission**	Environmental Commission**	City Council
12/6/04	12/15/04	1/4/05	1/12/05	12/16/04	1/24/05
12/20/04	12/29/04	1/18/05	1/12/05	1/27/05	2/14/05
1/3/05	1/12	2/1	2/9	1/27	2/28
1/18	1/26	2/15	2/9	2/24	3/14
1/31	2/9	3/1	3/9	2/24	3/28
2/14	2/23	3/15	3/9	3/24	4/11
3/7	3/16	4/5	4/13	3/24	4/25
3/21	3/30	4/19	4/13	4/28	5/9
4/4	4/13	5/3	5/11	4/28	5/23
4/18	4/27	5/17	5/11	5/26	6/13
5/9	5/18	6/7	6/8	5/26	6/27
5/23	6/1	6/21	6/8	6/23	7/11
6/6	6/15	7/5	7/13	6/23	7/25
6/20	6/29	7/19	7/13	7/28	8/8
7/5	7/13	8/2	8/10	7/28	8/22
7/18	7/27	8/16	8/10	8/25	9/12
8/8	8/17	9/6	9/14	8/25	9/26
8/22	8/31	9/20	9/14	9/22	10/10
9/6	9/14	10/4	10/12	9/22	10/24
9/19	9/28	10/18	10/12	10/27	11/14
10/3	10/12	11/1	11/9	10/27	11/28
10/17	10/26	11/15	11/9	11/17	12/12
11/7	11/16	12/6	12/14	11/17	12/27*
11/21	11/30	12/20	12/14	12/22*	1/9/06
12/5	12/14	1/3/06	1/11/06	12/22*	1/23/06

* Possible Change of Date

** Not all requests require an appearance before the Park and Recreation Commission or the Environmental Commission. The applicant will be notified when an appearance before a Commission is <u>not</u> required.

CITY OF INVER GROVE HEIGHTS
8150 Barbara Avenue
Inver Grove Heights, MN 55077
(612) 450-2500 • (612) 450-2502 (fax)

Permit No_____

Type _____

APPLICATION FOR LAND ALTERATION PERMIT

*Date of Application*_____

Excavator

Excavator _____

Contact Person _____

Address _____

Telephone _____ Fax_____

Land Owner(s)

Land Owner _____

Address _____

Telephone _____ Fax_____

PID No. 20-_____

Legal Description Lot_____ Block_____ Addition_____

_____

Section_____ Township_____

Land Owner _____

Address _____

Telephone _____ Fax_____

PID No. 20-_____

Legal Description Lot_____ Block_____ Addition_____

_____

Section_____ Township_____

Description of Land Being Altered

General Location of Land Being Altered_____

_____

Purpose of Land Alteration_____

Value of Work $ _____ Estimated Start Date_____

Estimated Completion Date_____

Source and Composition of Fill_____

Cubic Yards of Fill _____ c.y.

Cubic Yards of Excavation _____ c.y.

Total Volume of Land Alteration =_____ c.y.

Total Area of Land Altered _____Acres

A. ***Plan Checking Fees***

100 - 500 Cubic Yards ..... NO FEE

501 TO 1,000 Cubic Yards $25.00

1,001 to 10,000 Cubic Yards $30.00

10,001 to 100,000 Cubic Yards $75.00
(For the first 10,000 Cubic Yards plus $25.00 for each additional 10,000 Cubic Yards or fraction thereof).

100,001 Cubic Yards or More $300.00
(For the first 100,000 Cubic Yards plus $50,00 for each additional 100,000 Cubic Yards or fraction thereof).

B. ***Grading Permit Fees***

100 - 500 Cubic Yards $25.00

501 to 1,000 Cubic Yards $50.00
(For the first 500 Cubic Yards plus $7.50 for each additional 100 Cubic Yards or fraction thereof).

1,001 to 10,000 Cubic Yards $87.50
(For the first 1,000 Cubic Yards plus $12.50 for each additional 1,000 Cubic Yards or fraction thereof).

10,001 to 100,000 Cubic Yards $200.00
(For the first 10,000 Cubic Yards, plus $16.00 for each additional 10,000 Cubic Yards or fraction thereof).

100,001 Cubic Yards or more $350.00
(For the first 100,000 Cubic Yards, plus $25.00 for each additional 100,000 Cubic Yards or fraction thereof).

A. Plan Checking Fee $ _____

B. Grading Permit Fee $ _____

Total Fee (A + B) $ _____

Amount of Bond $ _____
($5,000 per acre, minimum $10,000; Must be submitted upon approval of application, if applicable).

Attachments to Application ***(The following plans, drawings, calculations, bonds and/or statements are required by the City Engineer).***

- ☐ Half-section map or sketch of property showing all adjacent property indicating the existing buildings and/or structures.
- ☐ Grading plan showing existing and proposed finished contours and elevations.
- ☐ Drainage plan showing existing and proposed drainage ways, culverts, storm sewer pipe, drainage structures, stabilization walls, retaining walls, cribbing, dams, or other protective items.
- ☐ Calculations for and approximate quantities of excavation and/or fill required.
- ☐ Signed statement from the property owner accepting responsibility for the operation and granting permission for land alteration/mining operation.
- ☐ Statement to be attached to deed advising of potential need for soil tests prior to any construction on lots where additional fill material has been placed.
- ☐ Sediment and erosion control plan meeting the requirements of the City of Inver Grove Heights City Code 430: Stormwater Management.
- ☐ Conformance with the City of Inver Grove Heights Water Resource Management Plan.
- ☐ Soil borings.
- ☐ Conformance with the City of Inver Grove Heights' Tree Preservation Ordinance.
- ☐ A final use plan, illustrating the ultimate land uses projected for the property.
- ☐ Location and surface type of access roads.
- ☐ Certification of Comprehensive General Liability Insurance.
- ☐ Compaction and/or Soil Density Requirements.
- ☐ Other: _____

Stipulations

1. A surety bond or certified check in the amount of $_____ ($5,000 per acre, minimum $10,000) must be submitted after approval of application and prior to any work. This bond or check is to ensure satisfactory performance and compliance with the below stated stipulations. The surety bond or check shall be kept active until the completion work and/or expiration of permit and can only be released by written notification of the City after a satisfactory final inspection has been performed by the City.
2. All access and street frontage of the land site must be controlled by a fence, a minimum of four (4) feet in height. All entrances must have gates that are capable of being locked.
3. Only rock, sand, gravel, dirt or similar natural earth fill is permitted. No concrete, asphalt, or demolition wastes will be permitted as fill unless a demolition landfill permit is first obtained from Dakota County (see attached).
4. Operations shall be limited to the hours of 7:00 a.m. to 7:00 p.m., Monday - Saturday, and shall not interfere with the health and safety of surrounding residents and the premises shall be maintained at all times so as not to create a nuisance.
5. Any explosives used must be done so in accordance with Inver Grove Heights Code and any other applicable standards, e.g., Federal, State, Industrial, etc. Obtain all required permits.
6. At end of each season's operations and no later than the last day of December, each year, the site is to be left in a neat and orderly condition, with maximum slopes of 3:1 with no overhang of vertical banks and with a level bottom.
7. Each day, or when required by the City, material from this operation that is found to exist on City streets shall be cleaned to the City's satisfaction by the applicants.
8. Upon completion of land alteration operations, the land must be left according to the plans and contours submitted with this application and planted with vegetation (subject to approval by the City) to prevent erosion.
9. Upon completion of land alteration operations or expiration of this permit, an inspection will be made by the City of the premises and adjoining streets. Any damage to have been caused by these operations will be corrected by the applicant upon notification of the City.

_____ Date_____
Applicant's Signature

_____ Date_____
Property Owner's Signature

_____ Date_____
Property Owner's Signature

CITY USE ONLY

Recommended for Approval ☐ Yes ☐ No By_____ Date_____

Recommended for Approval ☐ Yes ☐ No By____City Council_____ Date_____

Bond No. _____ Date Bond Expires_____

Insurance Company_____ Date Insurance Expires_____

Date:_____

PETITION FOR LOCAL IMPROVEMENT

CITY OF INVER GROVE HEIGHTS
DAKOTA COUNTY, MINNESOTA

We, the undersigned, owners of not less than thirty-five (35) percent in frontage of real property abutting an existing or proposed street, hereby petition for that existing or proposed street, pursuant to Minnesota Statutes, Chapter 429, be improved by the improvement(s) checked below, to wit:

- ☐ Bituminous Surfacing
- ☐ Grading
- ☐ Concrete Surfacing
- ☐ Installation of Curbs and Gutters
- ☐ Construction of Water Mains and Necessary Appurtenances therein
- ☐ Construction of Storm Sewer and Necessary Appurtenances therein
- ☐ Construction of Sanitary Sewer and Necessary Appurtenances therein
- ☐ Construction of Sidewalks Therealong
- ☐ Installation of Street Lighting Therealong
- ☐ Other (Specify):_____

DESCRIPTION OF STREET OR WORK AREA:

_____

_____

Owner Signature	P.I.D. or Property Description	Frontage
1. _____ Name _____ Address	20-_____ P.I.D. No. _____ Property Description	_____Feet
2. _____ Name _____ Address	20-_____ P.I.D. No. _____ Property Description	_____Feet
3. _____ Name _____ Address	20-_____ P.I.D. No. _____ Property Description	_____Feet
4. _____ Name _____ Address	20-_____ P.I.D. No. _____ Property Description	_____Feet
5. _____ Name _____ Address	20-_____ P.I.D. No. _____ Property Description	_____Feet
6. _____ Name _____	20-_____ P.I.D. No. _____	_____Feet

PRELIMINARY PLATS

PETITIONER'S INSTRUCTIONS

ALL REQUESTS FOR PRELIMINARY PLATS SHALL BE FILED WITH THE CITY'S PLANNING DIVISION. THE FOLLOWING DOCUMENTATION SHALL ACCOMPANY ALL REQUESTS BEFORE A REQUEST IS ACCEPTED FOR PROCESSING:

1) A completed Planning Application Form with fees and including all information listed below.

2) Provide an Abstractor's Certificate of the names and addresses of the owners of property within 350 feet of the boundaries of the property under consideration or properties within 1,000 feet if the property is not to be served by city sewer and water.

   (Source of such information is the Dakota County Abstract Company, located at 1250 Highway 55, Hastings, Minnesota 55113, (651-437-5600) – **MAY NEED TWO (2) WEEKS NOTICE FOR PREPARATION.** North Star Title (multiple metro locations). Universal Title Insurance Company (multiple metro locations).

3) Thirteen (13) folded full size copies plus one set of 11 x 17 reductions of the following:

   a) Exact Legal Description(s) of the Property to be platted.

   b) Preliminary Plat

      Containing the information as specified in Section 510.07, Subd. 2.

   c) Grading and Drainage Plan

      Including earthwork quantities, final grades (3:1 maximum slopes, 4:1 preferred maximum), building pad elevations, existing and proposed topography, drainage calculations, 10-year storm pipe design, 100-year storm level of protection, direction of drainage around each building pad location, appropriate easements as required.

   d) Erosion Control Plan

      Including method, location and detail of erosion control measures.

e) Utility Plan

Plan and profile showing existing utilities, proposed utilities, connection with existing utilities (watermain, sanitary sewer, storm sewer) appropriate easements as required.

Note whether utilities will be publicly or privately constructed, owned and maintained.

For plats in the non-utilitied portion of the city note drainfield locations on proposed lots. (Must be located on undistrubed soil.)

f) Street Plan

Plan and profile showing internal roads, grades, lengths of cul-de-sacs, curb data (horizontal and vertical), connection to existing streets or platted right-of-way, provisions for future extensions or connections to adjacent land, appropriate easements of right-of-way.

g) Street Signage Plan

Plan showing location and details for all street signage. This must include all street name signs, regulatory signs, and warning signs that are to be located within any public or private street right-of-ways associated with the project. The street signage plan does not include fire lane signage, which will be addressed by the Fire Marshal together with issuance of building permits.

h) Wetland Plan

Plan showing fill or draining of any wetland including sequencing justification and proposed mitigation consistent with the Wetland Conservation Act. All wetlands must be delineated in accordance with the Wetland Conservation Act.

i) Tree Preservation Plan

Plan showing location, size and specie of all significant trees (8 caliper inches or greater for deciduous trees, 10 feet in height for coniferous trees), including trees to be preserved, removed and those within 30 feet of grading limits.

j) Reforestation or Landscape Plan

Plan showing reforestation required by City Code Section 515.90. Subd. 28 and landscaping required by City Code Section 515.90. Subd. 10. Plan must identify location, size, species and quantity of plant materials.

k) Urban Development Concept Plan

All lands guided for residential development by the Comprehensive Plan that are located within the "A" Agricultural, "E-1" and "E-2"Estate Zoning Districts, are outside of the Metropolitan Urban Service Area (MUSA), and have a gross land area of 20.0 acres or more shall provide a concept plan indicating the manner in which land could be developed at urban densities. The Urban Development Concept Plan should be designed to current subdivision standards for urban development. In designing the subdivision, the following considerations shall be made:

a. The proposed street layout for the urban subdivision overlay may, at the discretion of the City Council, be required to integrate with the rural plat to maximize the use of existing built roadways and connections to off-site systems. All street right-of-ways for the Urban Development Concept Plan may, at the discretion of the City Council, be required to be platted as part of the rural plat to secure the integrity of future urban platting.

b. Lot size and arrangement may, at the discretion of the City Council, be required to be based on the R-1C One-Family Residential District standards. House pad locations for the rural development may, at the discretion of the City Council, be required to be indicated on the concept plan and be consistent with urban zoning standards so as to maximize efficient resubdivision of the rural lots into urban lots.

c. Areas for potential park land dedication and trail connections shall be identified as Outlots that are suitable for dedication to the City if required by the City Council.

d. The potential location of easements for drainage, municipal water, sanitary sewer, and storm sewer systems may, at the discretion of the City Council, be required to be shown in the Urban Development Concept Plan, including connection points for utility systems at the plat boundaries. Such easements may be required to be dedicated together with the rural plat if the City Council requires it.

e. The preliminary storm drainage system design may, at the discretion of the City Council, be required to include proper pipe

sizing and storm water ponding improvements for the urban development.

l) Letter from Dakota County or MN/DOT

Containing recommendations on access or right-of-way requirements, if the property abuts county or state roads or right-of-way, or proposes access to a state or county road.

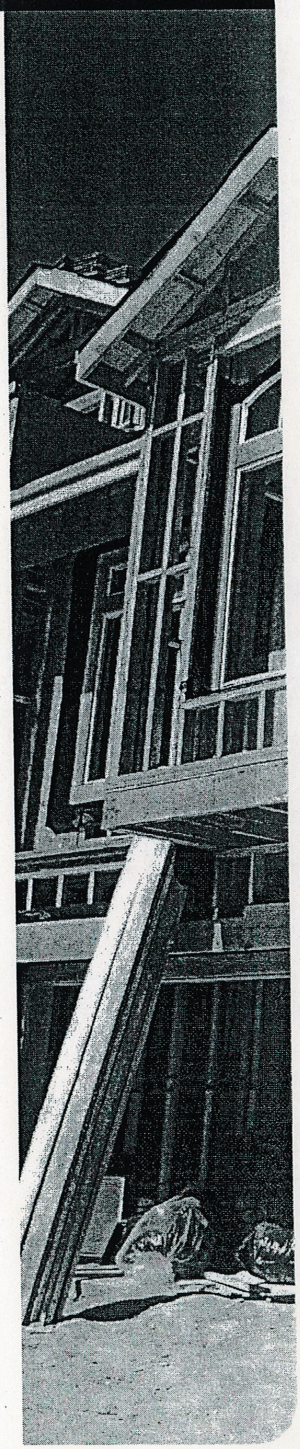
Other Possible Agency Reviews

- MN/DOT - When a proposed plat is adjacent to state right-of-way or road, or access to a state road is proposed.
- Dakota County - When a proposed plat is adjacent to a county right-of-way or road, or access to a county road is proposed.
- DNR - For subdivisions, Planned Unit Developments in a Shoreland Overlay Zone, or for variances requested from the Shoreland Management standards.
- U.S. Army Corps of Engineers - Permits are required for fills exceeding one acre in identified wetlands.
- EQB (Minnesota Environmental Quality Board) - Projects requiring environmental review.
- Any other applicable agency or jurisdiction.

MINNESOTA DEVELOPER CHECKLIST

BUILDERS CALL LINE 1-800-628-2121

We've developed this checklist as a helpful tool for you to use when planning and scheduling your utility services for your residential or commercial developments. Your project may require design, scheduling, site visits and permitting, therefore please provide as much advance notice as possible so we can ensure the most timely installation of your services. By taking these factors into consideration, we can help you keep your project on schedule and eliminate delays. Please contact the **Xcel Energy Builders Call Line at 1-800-628-2121** to schedule any of the following services:



- ◯ Relocating existing gas or electric facilities that are in conflict with the new development.
- ◯ Disconnecting gas and electric services to existing homes on the site that will be moved or demolished for the new development.
- ◯ Determining temporary electric needs to serve:
  - Existing buildings that are required to remain in service while you prepare the site and complete development
  - Sales or construction trailers
- ◯ Moving or burying transmission lines.
  Please note: this service requires at least six months advance notice to allow for permitting. Due to the expense, we provide this service on a limited basis.
- ◯ Submitting overhead to underground request for existing overhead distribution.

Telephone and Cable

- ◯ We recommend that you notify your appropriate phone & cable companies as soon as possible for under grounding requests or modifications to their systems.

Thank you for your assistance and we look forward to working with you.

Builders Call Line
1518 Chestnut Ave.
Minneapolis, MN 55403
1-800-628-2121
www.xcelenergy.com

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Northern States Power Company d/b/a Xcel Energy
03-08-109R 6/04 CSS# 1581

Xcel Energy™

2004 JOINT TRENCH CONTACTS - METRO EAST

Name	Title	Office Number	Nextel Number	E-Mail Address
XCEL ENERGY				
Builders Call Line		**800 628 2121**		
Electric Emergency		**800 895 1999**		
Natural Gas Emergency		**800 895 2999**		
Jerry Vehrs	Joint Trench Field Coordinator - Metro East	651 229 2277	612 369 4530	jerome.e.vehrs@xcelenergy.com
Dave Horejsi	Joint Trench Coordinator	651 229 5537	612 369 3993	david.m.horejsi@xcelenergy.com
Tim Virant	Manager, Contracting	651 229 5532	612 369 4535	tim.j.virant@xcelenergy.com
Becky Harasyn	New Development Liaison	651 748 3333	612 723 5012	becky.l.harasyn@xcelenergy.com
Cindy Pariseau	Xcel Local Crew Construction Coordinator	651 779 3514	612 720 3799	cynthia.k.pariseau@xcelenergy.com
MUELLER PIPELINERS				
Bert Veen	Manager, Joint Trench	651 762 8600	612 369 4516	bveen@exelonunderground.com
Doug Cabak	Joint Trench Designer	952 829 4579	612 282 5598	douglas.m.cabak@xcelenergy.com
Troy Nodes	Joint Trench Designer	651 748 3340	612 369 0822	troy.b.nodes@xcelenergy.com
Gary Kammerude	Conduit Crossing		612 369 2734	
COMCAST CABLE				
Brad Greenwaldt	New Build Supervisor	651 493 5307	651 755 2445	bradley_Greenwaldt@cable.comcast.com
CITIZENS/GTE/FRONTIER				
Doug Roush		651 257 3151	612 209 5763	droush@czn.com
CONNEXUS				
Tim Bergh	Line Superintendent	763 323 4226	763 286 2249 612 369 4433	timbe@connexusenergy.com
QWEST COMMUNICATIONS				
John Driscoll	Metro South	612 861 8745	612 250 8059	jadrisc@qwest.com
Denny Hoel	Metro East	651 229 4643	612 275 1558	dhoel@qwest.com
Jason Perkins	Cottage Grove - Woodbury, Northfield	651 777 8666	651 231 5748	jpperki@qwest.com
Wayne Johnson	White Bear, Stillwater, Lake Elmo, Forest Lake	651 282 8077	612 275 1567	wajohns@qwest.com
Jim Sanders	Metro North	651 281 7000	612 267 2035	jesanders@qwest.com
Ross Larson	Manager Design Engr.	651 714 7541	651 276-6426	rjlars2@qwest.com
U.S. CABLE				
John Fischer	Manager	320 980 3517		

Xcel Energy℠

Builders Call Line
1518 Chestnut Avenue
Minneapolis, MN 55403
(800) 628-2121
www.xcelenergy.com

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Northern States Power d/b/a Xcel Energy
04-03-409

NEW PLAT SUBMITTAL FORM
NEW RESIDENTIAL DEVELOPMENT

Xcel Energy™

Builders Call Line • 1518 Chestnut Avenue • Minneapolis, MN 55403
Phone: 612-623-2000 or 1-800-628-2121 Fax: 1-800-628-2521
www.xcelenergy.com

Please photocopy this page for multiple use.

Developer Name:_____ Today's Date: _____

Phone: ( ) _____ Contact: _____ Fax: ( ) _____

Pager: ( )_____ Cell Phone: ( )_____ Other Contact Number: ( ) _____

Mailing Address: _____ City: _____ State: _____ Zip: _____

*Email Address: _____

*By providing your e-mail, you are giving us permission to send information about this and other Xcel Energy products, services and events

Project Information

Development Name:_____ Contact: _____ Phone: ( )_____

Type of Development: ○ Single-Family Number of Lots: _____ ○ Multi-Family Number of Units:_____

Existing Homes on Site: ○ Yes ○ No Development Served By: ○ City Water/Sewer ○ Septic/Well

Road Requirements: ○ Curb and Gutter ○ Sidewalk ○ Rural Ditch Section

Paving: ○ Yes ○ No Association common area/community area/swimming pool: ○ Yes ○ No

Association Sprinkler System: ○ Yes ○ No Sprinkler system electric locations(cross streets): _____

Commercial Buildings: ○ Yes ○ No Fountains: ○ Yes ○ No 3 Phase Requirements: ○ Yes ○ No

Requested Services: ○ Electric ○ Gas ○ Street Lighting

List any special conditions that might require an on-site meeting to determine energy routing: _____

_____

Location

If Plats Included skip this section

Site Location: _____

Nearest Crossroads: _____

Section:_____ City/Town/Village (circle one)

Schedule

Two full sets of construction plans enclosed: ○ Yes ○ No

Approval Stage: ○ Conceptual ○ Preliminary ○ Final

Construction Start Date: _____ Electric/Gas Target Install Date: _____

THIS SECTION FOR Xcel Energy USE ONLY

Xcel Energy Street Lights Project? ○ Yes ○ No Work Order #: _____ Designer: _____

GIS DATA:

File ID:_____ Received From: _____ Date Received:_____

Format: ○ Paper ○ Digital Type: _____

Conversion Area: ○ Future ○ Current

Date Landbase Created In GIS:_____ Date Street Centerlines and Address Created in GIS: _____

Date Designer Notified: _____

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III. Construction Inspection Checklists

Bioretention - Construction Inspection Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Soil tested for permeability		
Project benchmark near site		
Facility location staked out		
Temporary erosion and sediment protection properly installed		
2. Excavation		
Lateral slopes completely level		
Soils not compacted during excavation		
Longitudinal slopes within design range		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/or silt fence		
3. Structural Components		
Stone diaphragm installed per plans		
Outlets installed pre plans		
Underdrain installed to grade		
Pretreatment devices installed per plans		
Soil bed composition and texture conforms to specifications		
4. Vegetation		
Complies with planting specs		

Bioretention - Construction Inspection Checklist		
Topsoil complies with specs in composition and placement		
Soil properly stabilized for permanent erosion control		
5. Final Inspection		
Dimensions per plans		
Pretreatment operational		
Inlet/outlet operational		
Soil/ filter bed permeability verified		
Effective stand of vegetation stabilized		
Construction generated sediments removed		
Contributing watershed stabilized before flow is diverted to the practice		
Comments:		

Bioretention - Construction Inspection Checklist

Actions to be taken:

Media Filter System - Construction Inspection Checklist

Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Soil tested for permeability		
Project benchmark near site		
Facility location staked out		
Temporary erosion and sediment protection properly installed		
2. Excavation		
Side slopes stable		
Foundation cleared of debris		
Excavation does not compact subsoil, if infiltration component of design		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
3. Structural Components		
Materials per specifications		
Forms adequately sized		
Concrete meets standards		
Prefabricated joints sealed		
Under-drains (size, materials) per specifications		
4. Vegetation		
Contributing area stabilized with vegetation and/ or erosion blankets		
Filter material per specification		

Media Filter System - Construction Inspection Checklist		
Under-drains installed to grade		
Flow diversion structure installed per plans		
Pre-treatment devices installed per plans		
Level overflow weirs, multiple orifices, distribution slots		
5. Final Inspection		
Dimensions per plans		
Surface completely level		
Pre-treatment device operational		
Structural components operational		
Inlet/ outlet operational		
Contributing watershed stabilized before flow is diverted to the practice		

Comments:

Media Filter System - Construction Inspection Checklist

Actions to be taken:

Vegetative Filter System - Construction Inspection Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Project benchmark near site		
Facility location staked out		
Temporary erosion and sediment protection properly installed		
2. Excavation		
Size and location per plans		
Side slopes stable		
Soil permeability verified		
Groundwater / bedrock verified		
Lateral slopes completely level		
Longitudinal slopes within design range		
Subsoils not compacted during excavation		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
3. Check Dams		
Dimensions per plans		
Spacing and grade installed per plans		
Materials per specifications		
4. Structural Components		
Filter material per specification		
Under-drains installed to grade		

Vegetative Filter System - Construction Inspection Checklist		
Under-drain installed per plans		
Inlet installed per plans		
Pre-treatment devices installed per plans		
5. Vegetation		
Dimensions per plans		
Check dams operational		
Inlet / outlet operational		
Effective stand of vegetation and stabilization		
Contributing watershed stabilized before flow is routed to the facility		
Comments:		

Vegetative Filter System - Construction Inspection Checklist

Actions to be taken:

Infiltration Trench - Construction Inspection Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Soil permeability verified		
Groundwater / bedrock verified		
Project benchmark established		
Facility location staked out		
Temporary erosion and sediment control established		
2. Excavation		
Size and location per plans		
Side slopes stable		
Depth adjusted to soil layer with specified soil type and permeability		
Sub-soil not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
3. Filter Fabric Placement		
Fabric per specifications		
Placed per plan location		
4. Aggregate Material		
Size as specified		
Clean / washed material		

Infiltration Trench - Construction Inspection Checklist		
Placed properly		
5. Observation Well		
Pipe size per plans		
Under-drain installed per plans		
Inlet installed per plans		
Pre-treatment devices installed per plans		
6. Vegetation		
Complies with planting specifications		
Topsoil complies with composition and placement in specifications		
Permanent erosion control measures in place		
7. Final Inspection		
Dimensions per plans		
Check dams operational		
Inlet / outlet operational		
Effective stand of vegetation and stabilization		
Contributing watershed stabilized before flow is routed to the facility		
Comments:		
Actions to be taken:		

Infiltration Basin - Construction Inspection Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Soil permeability verified		
Groundwater / bedrock verified		
Project benchmark established		
Facility location staked out		
Temporary erosion and sediment control established		
2. Excavation		
Size and location per plans		
Side slopes stable		
Depth adjusted to soil layer with specified soil type and permeability		
Sub-soil not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
3. Embankment		
Anti-seep collar or filter diaphragm per plans		
Fill material per specifications		
4. Final Excavation		
Drainage area stabilized		
Sediment removed from facility		

Infiltration Basin - Construction Inspection Checklist		
Basin floor tilled		
Facility stabilized		
Removable cap / footplate per plans		
Initial depth = _____ feet		
5. Final Inspection		
Pre-treatment facility operational		
Contributing watershed stabilized prior to flow diversion		
Inlet and outlet operational		
Comments:		

Infiltration Basin - Construction Inspection Checklist

Actions to be taken:

Stormwater Pond/ Wetland - Construction Inspection Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Construction Sequence	Satisfactory/ Unsatisfactory	Comments
1. Pre-Construction/Materials and Equipment		
Pre-construction meeting		
Pipe and appurtenances on-site prior to construction and dimensions checked		
1. Material (including protective coating, if specified)		
2. Diameter		
3. Dimensions of metal riser or pre-cast concrete outlet structure		
4. Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans		
5. Barrel stub for prefabricated pipe structures at proper angle for design barrel slope		
6. Number and dimensions of prefabricated anti-seep collars		
7. Watertight connectors and gaskets		
8. Outlet drain valve		
Project benchmark near pond site		
Facility location staked out		
Equipment for temporary de-watering		
Temporary erosion and sediment control in place		
2. Subgrade Preparation		
Area beneath embankment stripped of all vegetation, topsoil, and organic matter		
3. Pipe Installation		
Method of installation detailed on plans		
A. Bed preparation		
Installation trench excavated with specified side slopes		

Stormwater Pond/ Wetland - Construction Inspection Checklist		
Stable, uniform, dry subgrade of relatively impervious material (If subgrade is wet, contractor shall have defined steps before proceeding with installation)		
Invert at proper elevation and grade		
B. Pipe placement		
Metal / plastic pipe		
1. Watertight connectors and gaskets properly installed		
2. Anti-seep collars properly spaced and having watertight connections to pipe		
3. Backfill placed and tamped by hand under “haunches” of pipe		
4. Remaining backfill placed in max. 8 inch lifts using small power tamping equipment until 2 feet cover over pipe is reached		
Concrete pipe		
1. Pipe set on blocks or concrete slab for pouring of low cradle		
2. Pipe installed with rubber gasket joints with no spalling in gasket interface area		
3. Excavation for lower half of anti-seep collar(s) with reinforcing steel set		
4. Entire area where anti-seep collar(s) will come in contact with pipe coated with mastic or other approved waterproof sealant		
5. Low cradle and bottom half of anti-seep collar installed as monolithic pour and of an approved mix		
6. Upper half of anti-seep collar(s) formed with reinforcing steel set		

Stormwater Pond/ Wetland - Construction Inspection Checklist		
7. Concrete for collar of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
8. Forms stripped and collar inspected for honeycomb prior to backfilling. Parge if necessary.		
C. Backfilling		
Fill placed in maximum 8 inch lifts		
Backfill taken minimum 2 feet above top of anti-seep collar elevation before traversing with heavy equipment		
4. Riser / Outlet Structure Installation		
Riser located within embankment		
A. Metal riser		
Riser base excavated or formed on stable subgrade to design dimensions		
Set on blocks to design elevations and plumbed		
Reinforcing bars placed at right angles and projecting into sides of riser		
Concrete poured so as to fill inside of riser to invert of barrel		
B. Pre-cast concrete structure		
Dry and stable subgrade		
Riser base set to design elevation		
If more than one section, no spalling in gasket interface area; gasket or approved caulking material placed securely		
Watertight and structurally sound collar or gasket joint where structure connects to pipe spillway		
C. Poured concrete structure		
Footing excavated or formed on stable subgrade, to design dimensions with reinforcing steel set		

Stormwater Pond/ Wetland - Construction Inspection Checklist		
Structure formed to design dimensions, with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing while curing, if necessary)		
Forms stripped & inspected for honeycomb prior to backfilling; parge if necessary		
5. Embankment Construction		
Fill material		
Compaction		
Embankment		
1. Fill placed in specified lifts and compacted with appropriate equipment		
2. Constructed to design cross-section, side slopes and top width		
3. Constructed to design elevation plus allowance for settlement		
6. Impounded Area Construction		
Excavated / graded to design contours and side slopes		
Inlet pipes have adequate outfall protection		
Forebay(s) constructed per plans		
Pond benches construction per plans		
7. Earth Emergency Spillway Construction		
Spillway located in cut or structurally stabilized with riprap, gabions, concrete, etc.		
Excavated to proper cross-section, side slopes and bottom width		
Entrance channel, crest, and exit channel constructed to design grades and elevations		
8. Outlet Protection		
A. End section		

Stormwater Pond/ Wetland - Construction Inspection Checklist		
Securely in place and properly backfilled		
B. Endwall		
Footing excavated or formed on stable subgrade, to design dimensions and reinforcing steel set, if specified		
Endwall formed to design dimensions with reinforcing steel set as per plan		
Concrete of an approved mix and vibrated into place (protected from freezing, if necessary)		
Forms stripped and structure inspected for honeycomb prior to backfilling; parge if necessary		
C. Riprap apron / channel		
Apron / channel excavated to design cross-section with proper transition to existing ground		
Filter fabric in place		
Stone sized as per plan and uniformly place at the thickness specified		
9. Vegetative Stabilization		
Approved seed mixture or sod		
Proper surface preparation and required soil mendments		
Excelsior mat or other stabilization, as per plan		
10. Miscellaneous		
Drain for ponds having a permanent pool		
Trash rack / anti-vortex device secured to outlet structure		
Trash protection for low flow pipes, orifices, etc.		
Fencing (when required)		
Access road		
Set aside for clean-out maintenance		
11. Stormwater Wetlands		

Stormwater Pond/ Wetland - Construction Inspection Checklist		
Adequate water balance		
Variety of depth zones present		
Approved pondscaping plan in place and budget for additional plantings		
Plants and materials ordered 6 months prior to construction		
Construction planned to allow for adequate planting and establishment of plant community (April-June planting window)		
12. Final Inspection		
Construction sediment removed from settling basin		
Contributing drainage area stabilized		
Vegetation established per specifications		
Inlet and outlet structures operational		

IV. Operations and Maintenance

Long term performance of BMPs is ensured with proper operation and regular maintenance. Maintenance is necessary to prevent the following problems (CWP, 2004):

- ► Sediment accumulation, reduction in storage volume
- ► Debris blockage of structures
- ► Structural damage
- ► Invasive plants
- ► Loss of slope stabilization vegetation
- ► Reduced structural integrity of embankments, weirs or risers

Therefore, it is REQUIRED that site designers communicate how to maintain the BMP in an Operation and Maintenance (O&M) Plan. Owners and maintenance staff will be able to reference this plan, for example, when they have questions about sediment removal, valve operation, or capacity for future site expansion. At a minimum the contents of an O&M manual should include:

- ► Detailed inspection and maintenance requirements/tasks
- ► Inspection and maintenance schedules
- ► Parties legally responsible for maintenance (name, address, and telephone number)
- ► Provisions for financing of operation and maintenance activities
- ► As-built plans of completed structures
- ► Letter of compliance from the designer
- ► Post-construction documentation to demonstrate compliance with maintenance activities

The following checklists for the BMPs recommended in this Manual are intended to supplement the O&M Plan requirements.

Additional guidance for individual stormwater treatment practices in provided in Chapter 8 of this manual. This guidance breaks the operation and maintenance requirements of BMPs into the following categories:

- ► Design Phase Maintenance Considerations
- ► Construction Phase Maintenance
- ► Post-Construction Operation and Maintenance

Stormwater Managers/Designers seeking more detailed background information are encouraged to research information available from the Center for Watershed Protection, the Toronto SWAMP program, the US EPA; or a local source, such as the City of Plymouth Pond Maintenance Policy.

Bioretention - Operation & Maintenance Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Maintenance Item	Satisfactory / Unsatisfactory	Comments
1. Debris Cleanout (Monthly)		
Contributing areas clean of litter and vegetative debris		
No dumping of yard wastes into practice		
Bioretention area clean of litter and vegetative debris		
2. Vegetation (Monthly)		
Plant height taller than design water depth		
Fertilized per O&M plan		
Plant composition according to O&M plan		
Undesirable vegetation removed		
Grass height less than 6 inches		
No evidence of erosion		
3. Check Dams/Energy Dissipators/Sumps (Annual, After Major Storms)		
No evidence of sediment buildup		
Sumps should not be more than 50% full of sediment		
No evidence of erosion at downstream toe of drop structure		
4. Dewatering (Monthly)		
Dewaters between storms within 72 hours/ 48 hours for MPCA permit		
No evidence of standing water		
5. Sediment Deposition (Annual)		
Pretreatment areas clean of sediments		

Bioretention - Operation & Maintenance Checklist		
Contributing drainage area stabilized and clear of erosion		
Winter sand deposition evacuated every spring		
6. Outlet/Overflow Spillway (Annual, After Major Storms)		
Good condition, no need for repair		
No evidence of erosion		
No evidence of any blockages		
7. Integrity of Filter Bed (Annual)		
Filter bed has not been blocked or filled inappropriately		
Comments:		
Actions to be Taken:		

Media Filter System - Operation & Maintenance Checklist

Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Maintenance Item	Satisfactory / Unsatisfactory	Comments
1. Debris Cleanout (Monthly)		
Contributing areas clean of litter and vegetative debris		
Filtration facility clean		
Inlet and outlets clear		
2. Oil and Grease (Monthly)		
No evidence of filter surface clogging		
Activities in drainage area minimize oil and grease entry		
3. Vegetation (Monthly)		
Contributing drainage area stabilized		
Undesirable vegetation removed		
No evidence of erosion		
Area mowed and clipping removed		
4. Sediment Traps and Forebays (Monthly)		
Water holding chambers at normal pool		
No evidence of leakage		
Obviously trapping sediment		
Greater than 50% storage volume remaining		
5. Sediment Deposition (Annual)		
Filter chamber free of sediments		
Contributing drainage area stabilized and free of erosion		
6. Structural Components (Annual)		

Media Filter System - Operation & Maintenance Checklist		
No evidence of structural deterioration		
Any grates are in good condition		
No evidence of spalling or cracking of structural parts		
7. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		
No evidence of erosion (if draining into a natural channel)		
No evidence of blockages		
8. Overall Function of Facility (Annual)		
Evidence of flow bypassing facility		
No noticeable odors outside of facility		
Comments:		
Actions to be Taken:		

Vegetative Filter System - Operation & Maintenance Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Debris Cleanout (Monthly)		
Contributing areas clean of litter and vegetative debris		
Inlet and outlet clear		
Filtration facility clean		
2. Check Dams or Energy Dissipaters (Annual, After Major Storms)		
No evidence of flow going around structures		
No evidence of erosion at downstream toe		
3. Vegetation (Monthly)		
Mowing done per O&M plan		
Minimum mowing depth not exceeded		
Undesirable vegetation removed		
No evidence of erosion		
Fertilized per O&M plan		
4. Dewatering (Monthly)		
Dewaters between storms within 72 hours/ 48 hours for MPCA permit		
5. Sediment deposition (Annual)		
Clean of sediment		
Winter accumulation of sand removed each spring		
Contributing drainage area stabilized and free of erosion		
6. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repairs		

Vegetative Filter System - Operation & Maintenance Checklist		
No evidence of erosion		
No evidence of blockage		
Comments:		
Actions to be Taken:		

Infiltration Trench/ Basin - Operation & Maintenance Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Maintenance Item	Satisfactory / Unsatisfactory	Comments
1. Debris Cleanout (Monthly)		
Contributing drainage area clear of litter and vegetative debris		
Trench surface clean		
Inflow pipes clear		
Overflow spillway clear		
Inlet area clean		
2. Sediment Traps or Forebays (Annual)		
Obviously trapping sediment		
Greater than 50% of storage volume remaining		
3. Dewatering (Monthly)		
Trench dewaters between storms		
4. Vegetation (Monthly)		
Mowing done per O&M plan		
Minimum mowing depth not exceeded		
Undesirable vegetation removed		
No evidence of erosion		
Fertilized per O&M plan		
5. Sediment Cleanout of Trench (Annual)		
No evidence of sedimentation in gravel filter		
Sediment accumulation doesn't yet require cleanout		
6. Sediment deposition of Basin (Annual)		
Clean of sediment		
Winter accumulation of sand removed each spring		

Infiltration Trench/ Basin - Operation & Maintenance Checklist		
Contributing drainage area stabilized and free of erosion		
7. Inlets (Annual)		
Good condition		
No evidence of erosion		
8. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repair		
No evidence of erosion		
9. Aggregate Repairs (Annual)		
Surface of aggregate clean		
Top layer of stone does not need replacement		
Trench does not need rehabilitation		
Comments:		
Actions to be Taken:		

Stormwater Pond/ Wetland Operation & Maintenance Checklist		
Project:		
Location:		
Site Status:		
Date:		
Time:		
Inspector:		
Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Embankment and emergency spillway (Annual, After Major Storms)		
1. Vegetation and ground cover adequate		
2. Embankment erosion		
3. Animal burrows		
4. Unauthorized planting		
5. Cracking, bulging, or sliding of embankment		
a. Upstream face		
b. Downstream face		
c. At or beyond toe		
downstream		
upstream		
d. Emergency spillway		
6. Pond, toe & chimney drains clear and functioning		
7. Seeps/leaks on downstream face		
8. Slope protection or riprap failure		
9. Vertical/horizontal alignment of top of dam “As-Built”		
10. Emergency spillway clear of obstructions and debris		
11. Other (specify)		
2. Riser and principal spillway (Annual)		
Type: Reinforced concrete _____ Corrugated pipe _____ Masonry _____		
1. Low flow orifice obstructed		

Stormwater Pond/ Wetland Operation & Maintenance Checklist		
2. Low flow trash rack.		
a. Debris removal necessary		
b. Corrosion control		
3. Weir trash rack maintenance		
a. Debris removal necessary		
b. corrosion control		
4. Excessive sediment accumulation insider riser		
5. Concrete/masonry condition riser and barrels		
a. cracks or displacement		
b. Minor spalling (<1”)		
c. Major spalling (rebars exposed)		
d. Joint failures		
e. Water tightness		
6. Metal pipe condition		
7. Control valve		
a. Operational/exercised		
b. Chained and locked		
8. Pond drain valve		
a. Operational/exercised		
b. Chained and locked		
9. Outfall channels functioning		
10. Other (specify)		
3. Permanent Pool (Wet Ponds) (Monthly)		
1. Undesirable vegetative growth		
2. Floating or floatable debris removal required		
3. Visible pollution		

Stormwater Pond/ Wetland Operation & Maintenance Checklist		
4. Shoreline problem		
5. Other (specify)		
4. Sediment Forebays		
1. Sedimentation noted		
2. Sediment cleanout when depth < 50% design depth		
5. Dry Pond Areas		
1. Vegetation adequate		
2. Undesirable vegetative growth		
3. Undesirable woody vegetation		
4. Low flow channels clear of obstructions		
5. Standing water or wet spots		
6. Sediment and / or trash accumulation		
7. Other (specify)		
6. Condition of Outfalls (Annual , After Major Storms)		
1. Riprap failures		
2. Slope erosion		
3. Storm drain pipes		
4.Endwalls / Headwalls		
5. Other (specify)		
7. Other (Monthly)		
1. Encroachment on pond, wetland or easement area		
2. Complaints from residents		
3.Aesthetics		
a. Grass growing required		
b. Graffiti removal needed		
c. Other (specify)		
4. Conditions of maintenance access routes.		

Stormwater Pond/ Wetland Operation & Maintenance Checklist		
5. Signs of hydrocarbon build-up		
6. Any public hazards (specify)		
8. Wetland Vegetation (Annual)		
1. Vegetation healthy and growing Wetland maintaining 50% surface area coverage of wetland plants after the second growing season. (If unsatisfactory, reinforcement plantings needed)		
2. Dominant wetland plants: Survival of desired wetland plant species Distribution according to landscaping plan?		
3. Evidence of invasive species		
4. Maintenance of adequate water depths for desired wetland plant species		
5. Harvesting of emergent plantings needed		
6. Have sediment accumulations reduced pool volume significantly or are plants “choked” with sediment		
7. Eutrophication level of the wetland.		
8. Other (specify)		
Comments:		

INVER GROVE HEIGHTS
Northwest Area

Appendix E

Curve Number Derivation

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Curve Number Derivation

Appendix E

A brief summary of the process of determining the applicable CNs for the NWA is described in this appendix, for more detail; see the NWEA Modeling Report, 2006.

Contents

I. Introduction..... 3
II. Modeling Methodologies Examined..... 3
III. Comparison of Runoff Calculation Methods..... 3
IV. Green-Ampt to SCS Parameter Conversion..... 4
V. Conclusion..... 5
VI. Additional Considerations..... 5

I. Introduction

This section provides detail on the establishment of the hydrologic parameters to be used in the stormwater runoff calculations. The hydrologic parameters used to model runoff in the Northwest Area (NWA) of Inver Grove Heights have been calibrated based on monitoring data collected within the NWA and the monitoring data indicate that the standard hydrologic parameters (state and national data) should not be used for analysis within the NWA. Many of the state and national methods are designed to be used for large storms, in watersheds with large runoff fractions, and may not be appropriate for smaller rainfall events or smaller runoff fractions.

The SCS method and the Green-Ampt method were analyzed during the in the Inver Grove Heights NWA modeling process. SCS methodology is the principal methodology discussed in this section because it is the predominant method used by design engineers. Other runoff calculation methods may be accepted at the City Engineer's discretion, however sufficient documentation exhibiting the merits of another method and its hydrologic parameters within the NWA must be exhibited for such an exception to be warranted.

II. Modeling Methodologies Examined

SCS Method. The accuracy of the SCS methodology is described in the National Engineering Handbook, Part 630.1003, "Accuracy". This section states that the most common use of the SCS method is to "determine a design discharge [25-year, 100-year, probable maximum flood (PMF)] based on a synthetic rainstorm."[1] The probable maximum flood is the "flood that can be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in a region."[2] The PMF analysis uses extreme rainfall events that coincide with the worst-case scenarios for other hydrologic conditions. The National Engineering Handbook later states that the SCS method performed "poorly in cases where the runoff was a small fraction of the rainfall; i.e., the CNs are low or rainfall values are small."[3] The monitored runoff from the NWA in Inver Grove Heights was a very small fraction of the rainfall at all of the monitored locations. Therefore it would be expected that the SCS values would poorly reflect the actual runoff that occurred in the NWA.

Green-Ampt Method. While the SCS method has a standard set of state and national approved values, the Green-Ampt method has a large range of values that are used for runoff analyses. The SCS method also boils all the parameters into one value used for calculation, a curve number; while Green-Ampt method applies three variables in the runoff calculations. These variables all relate to soil properties; average capillary suction (S_u), initial moisture deficit (IMD) and saturated hydraulic conductivity (K_s). By far the most variable (and sensitive) of these parameters is K_s. The values recommended by the modeling software, XP-SWMM, have calibrated well in previous analyses, and were used as the starting point in the modeling process.

III. Comparison of Runoff Calculation Methods

Another important consideration in the transformation of Green-Ampt parameters to SCS, is an analysis of how each method calculates runoff. Table E.1 outlines the variables used for each method.

Table E.1. Hydrology Volume Calculation Variable Comparison

Green-Ampt	Area	% Impervious	Soil Type	Slope	Width
SCS*	Area	% Impervious	Soil Type	Land Cover	

*NOTE: Time of concentration is not shown because it does not affect the runoff volume, only the rate of runoff, whereas in Green-Ampt method, the slope and width parameters do affect the volume of runoff.

Green-Ampt methodology differs from SCS because it uses the slope and width for generation of runoff volume while SCS uses land cover. Theoretically, this difference is accentuated in areas with limited directly connected impervious surface and steep slopes, as prevalent in the NWEA, where using solely the land cover (as SCS methodology does) would result in minimal runoff, while using solely the width and steep slopes (as Green-Ampt does) should yield more runoff.

Because the soils in the NWA allowed such a small amount of runoff and because the Green-Ampt method does not account for the land use function, the hydraulic conductivity of the soil was increased by 50%. This resulted in a very good calibration to the large 6.4" rainfall event that was monitored.

IV. Green-Ampt to SCS Parameter Conversion

Using the aforementioned revisions and updating the model, the basin levels calibrated closer to monitored data. The model is still marginally conservative and generally overestimates the volume of runoff coming from the landscape. Table E.2 shows the output of the now calibrated Green-Ampt model after it was run for a 5-year, 24-hour rainfall event.

Table E.2. Green-Ampt Model Output

XP-SWMM Output	[3.6" Rainfall Event (5-year)]								
Subcatchment	EP-016a	EP-034	EP-036a	EP-066a	EP-071	EP-102a	EP-104	F-022	SP-7
Area (acres)	96.9	38.1	20.2	32.5	45.8	29.1	41.6	30.8	19.9
Percent Impervious	25.3	3.9	17.1	0	9.8	26.1	4.2	58.7	0
Total Rainfall (in)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Pervious Area									
Total Runoff Depth (in)	0.03	0.07	0.31	0.04	0.16	0.02	0.11	0.09	0.13
Total Area									
Total Runoff Depth (in)	0.90	0.21	0.86	0.04	0.49	0.92	0.11	2.07	0.13
CN (no vol. adjustments)	41	44	53	42	48	40	46	45	47
CN (MN Hydrology Guide)	65	67	67	53	62	70	71	60	62

The output of Table E.2 was generated because the five-year rainfall event (3.6" of rain in 24 hours) has been chosen as the design event for IGH. The goal of the conversion is to have curve numbers that generate similar volumes to those generated by the calibrated Green-Ampt model.

The runoff depth from pervious surfaces (row 5) was used to back-calculate an equivalent curve number to match the model results. That equivalent curve number is shown in row 7. The curve number calculated using the standard Minnesota Hydrology Guide curve numbers is shown below the calibrated values

(bottom row). The values recommended by the MN Hydrology Guide are, on average, 16 units larger than those indicated by the calibrated model. Clearly, using the curve numbers from the MN Hydrology Guide overestimates the volume of runoff that actually occurs in the Inver Grove Heights system for the relevant rainfall event. Therefore, some type of adjustment needed to be made to the recommended guide values so the SCS method can become appropriate.

V. Conclusion

Essentially the NWA soils and land cover produce much less stormwater runoff than predicted using the traditional Green-Ampt or SCS hydrologic parameters. Both methods predict more runoff volume than actually occurred as documented by the monitoring of basins in 2005. This indicates that the soils are actually allowing much less water to run off (infiltrating more) than similar soils in analogous Minnesota locations.

One means of quantifying this phenomenon is by using the hydrologic soil type values. Curve numbers are calculated by land cover and assigned based on A, B, C, or D type soils. “A” (sandy) soils allow maximum infiltration, while “D” (clayey) soils allow minimal infiltration. The vast majority of the soils in the NWA of Inver Grove Heights are “B” type soils. Many of these “A” and “B” soils in the NWA were re-classified as an “A/B” type soil based on many soil characteristics. The methodology used in making these modifications can be found in the May 12, 2006, “Northwest Expansion Area Hydrologic & Hydraulic Analysis Update and Gun Club Lake Modeling Report”. This resulted in an improved fit to the monitored volume generated during the 6.4” monitored rainfall event.

The Antecedent Moisture Condition (AMC) was also examined as a possibility for a curve number calibration for the NWA. The AMC is an adjustment factor used to modify the recommended curve numbers based on ground moisture conditions at the beginning of a rainfall event. The AMC is similar to the Green-Ampt parameter of initial moisture deficit, however it is traditionally assigned based on geographical area and not by soil type. There are three classes of AMC; the average condition is Class II, while drier conditions use Class I and wetter conditions use Class III. It was examined to determine if the soils in Inver Grove Heights infiltrate so well that a Class I AMC should be used to reflect the drier soil conditions. However, Class I AMC overcompensated by applying a curve number well below what the monitoring data indicated was occurring. A curve number averaging the AMC I and the AMC II values was developed, however this yielded results almost identical to the upgrading of soil classes previously discussed. The upgrading of soil classes is the more appropriate methodology, considering that more than two inches of rain had fallen within the ten days preceding the 6.4”, October 4-5, rainfall event to which the model was calibrated, indicating that the conditions were not “drier”. Any lack of moisture in the soil is due to the high capacity of the soil to infiltrate and not due to the Antecedent Moisture Condition.

Table E.5 gives a breakdown of the areas by cover type found in the subwatersheds with monitored basin data. The far right column indicates the curve number that would be used in the permitting process (calculated based on values shown in Table E.4), while the “Pervious Composite Target” column is the CN that was back-calculated from the calibrated model values. The highlighted cells indicate the accuracy the model had in mimicking the monitored levels, identifying whether the subwatershed model over predicted the runoff generated, under predicted it, or came very close to matching the actual runoff volume. The “MN Hydrology Guide CN” column shows the curve number that would be calculated using standard values (shown in Table E.3).

VI. Additional Considerations

Impervious surfaces that are directly connected to the downstream drainage feature are to be modeled independently of the pervious land cover or the impervious surfaces which have runoff directed over the pervious soils. The directly connected impervious surfaces should not composited (for more detail, see

Pretreatment section in Chapter 7 and the Example Site Design in Chapter 9). The XP-SWMM (RUNOFF) Green-Ampt method does not combine impervious surfaces and pervious surfaces; neither should they be combined in SCS methodology. This modeling method does not accurately reflect the calibrated model.

Table E.3. Pervious MN Hydrology Guide Recommended ARC II Curve Numbers						
	1	2	3	4	5	6
	Meadow	Woods	Woods & Meadow	Agricultural	Urban Open Space	Wetland*
Condition:	Fair	Fair	Good	Good	Good	N/A
A	35	36	32	51	39	75
A/B*	45	48	45	59	50	76
B	56	60	58	67	61	78
C	70	73	72	76	74	83
D	77	79	79	80	80	85

*Calculated average of A & B type soils, not found in MN Hydrology Guide
*Wetland values not assigned CN in MN Hydrology Guide

Overestimates runoff
Underestimates runoff
Good estimation

Table E.4. IGH Recommended Curve Numbers										
	1		2		3		4	5		6
	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland*
Soil Type	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A/B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

Table E.5. Subwatershed Acres by Cover Type & Soil Type

Acres of Cover Type							5-year, 24-hour Rainfall Event			
Soil Type	Meadow	Woods	Woods & Meadow	Agricultural	Graded Urban Open Space	Wetland*	TOTAL ACRES	Pervious Calibrated Target	MN Hydrology Guide CN	IGH Curve Number
EP-016a							73.1	41	50	38
A							0.0			
A/B	17.1	8.8	27.0			0.3	53.1		46	34
B	5.2	1.2	11.5			2.2	20.0		60	49
EP-034							38.1	44	57	47
A	0.9		0.4				1.3		34	32
A/B	2.6	2.2	2.5	7.2		0.2	14.7		53	43
B	4.3	3.5	8.2	4.1	0.7	1.3	22.1		61	51
EP-036a							20.2	53	59	49
A							0.0			
A/B	1.1		0.3			0.1	1.4		46	36
B	10.9	0.2	3.0	3.6		1.1	18.7		60	50
EP-66a							32.5	42	50	40
A	0.5						0.5		35	33
A/B	18.1	0.6	2.4	4.0			25.1		47	37
B	5.3	0.3	0.1	1.4			7.0		58	48
EP-71							44.6	48	60	50

Table E.3. Pervious MN Hydrology Guide Recommended ARC II Curve Numbers						
	1	2	3	4	5	6
	Meadow	Woods	Woods & Meadow	Agricultural	Urban Open Space	Wetland*
Condition:	Fair	Fair	Good	Good	Good	N/A
A	35	36	32	51	39	75
A/B*	45	48	45	59	50	76
B	56	60	58	67	61	78
C	70	73	72	76	74	83
D	77	79	79	80	80	85

*Calculated average of A & B type soils, not found in MN Hydrology Guide
*Wetland values not assigned CN in MN Hydrology Guide

	Overestimates runoff
	Underestimates runoff
	Good estimation

Table E.4. IGH Recommended Curve Numbers										
	1		2		3		4	5		6
	Meadow		Woods		Woods & Meadow		Agricultural	Urban Open Space		Wetland*
Soil Type	Undisturbed	Graded	Undisturbed	Graded	Undisturbed	Graded	Cultivated	Undisturbed	Graded	N/A
A	33	35	34	36	30	32	48	39	50	75
A/B*	35	45	36	48	32	45	51	50	61	76
B	45	56	48	60	45	58	59	61	74	78
C	56	70	60	73	58	72	67	74	80	83
D	70	77	73	79	72	79	76	80	80	85

Table E.5. Subwatershed Acres by Cover Type & Soil Type										
	Acres of Cover Type						5-year, 24-hour Rainfall Event			
Soil Type	Meadow	Woods	Woods & Meadow	Agricultural	Graded Urban Open Space	Wetland*	TOTAL ACRES	Pervious Calibrated Target	MN Hydrology Guide CN	IGH Curve Number
EP-016a							73.1	*41*	50	**38**
A							0.0			
A/B	17.1	8.8	27.0			0.3	53.1		46	34
B	5.2	1.2	11.5			2.2	20.0		60	49
EP-034							38.1	*44*	57	**47**
A	0.9		0.4				1.3		34	32
A/B	2.6	2.2	2.5	7.2		0.2	14.7		53	43
B	4.3	3.5	8.2	4.1	0.7	1.3	22.1		61	51
EP-036a							20.2	*53*	59	**49**
A							0.0			
A/B	1.1		0.3			0.1	1.4		46	36
B	10.9	0.2	3.0	3.6		1.1	18.7		60	50
EP-66a							32.5	*42*	50	**40**
A	0.5						0.5		35	33
A/B	18.1	0.6	2.4	4.0			25.1		47	37
B	5.3	0.3	0.1	1.4			7.0		58	48
EP-71							44.6	*48*	60	**50**
A							0.0			
A/B	3.3	0.2	4.4	4.9	0.1		12.9		50	40
B	5.0		9.6	13.8		3.3	31.8		64	55
EP-102a							29.1	*40*	57	**49**
A							0.0			
A/B	8.2		1.5	10.7		2.3	22.7		55	46
B	1.6		1.5	0.8		2.4	6.4		66	59

EP-104							41.6	*46*	61	**51**
A							0.0			
A/B	0.8		1.0	9.4			11.2		57	48
B	3.5		12.2	14.7			30.4		62	52
F-022							16.4	*45*	54	**43**
A							0.0			
A/B	0.0	0.9	5.2				6.1		45	33
B	1.7	0.2	7.3			1.1	10.3		60	49
SP-7							19.8	*47*	55	**46**
A							0.0			
A/B		3.1	3.2		0.2		6.5		47	35
B		2.3	8.4	0.3	2.4		13.4		59	51

[1] National Engineering Handbook. Part 630. 210-VI-NEH, July 2004. pg. 10-19.
[2] American Meteorological Society Web page Glossary. http://amsglossary.allenpress.com/glossary.
[3] National Engineering Handbook. Part 630. 210-VI-NEH, July 2004. pg. 10-19.

INVER GROVE HEIGHTS
Northwest Area

Appendix F

Guidance on Preparation of Construction and Maintenance Costs

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Guidance on Preparation of Construction and Maintenance Costs

Appendix F

Key Topics: cost estimates for select BMPs

Contents

I. Bioretention Cost Estimate..... 3
II. Infiltration Basin Cost Estimate..... 4
III. Stormwater Pond Cost Estimate..... 5
IV. Stormwater Wetland Cost Estimate..... 6
V. Surface Sand Filter Cost Estimate..... 7

BIORETENTION DEVICE
COST ESTIMATE WORKSHEET
2005 Prices

Project Title _____

Owner _____

Location _____

Project Number _____

Date _____

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Topsoil - salvage	square yard		$4.50	$0.00
Site Formation				
Excavation - 4' average depth	square yard		$10.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site	square yard		$6.50	$0.00
Structural Components				
Underdrain - with pea gravel and geotextile	lineal foot		$30.00	$0.00
Inlet structure	each		$1,500.00	$0.00
Outlet structure	each		$2,500.00	$0.00
Site Restoration				
Filter strip	square yard			$0.00
Soil preparation	square yard		$30.00	$0.00
Seeding - above outlet elevation	square yard		$0.50	$0.00
Planting - below outlet elevation	square yard		$30.00	$0.00
Mulch	square yard		$5.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Annual Operation and Maintenance				
Debris removal	per visit		$50.00	$0.00
Weed control	per visit		$50.00	$0.00
Sediment removal	per year		$500.00	$0.00
Replace planting media	square yard		$12.00	$0.00
Replace plants	per plant		$5.00	$0.00
Mow filter strips	per visit		$50.00	$0.00
Erosion repair	square yard		$75.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Bioretention BMPs. To be used for preliminary cost estimation.

INFILTRATION BASIN
COST ESTIMATE WORKSHEET
2005 Prices

Project Title _____

Owner _____

Location _____

Project Number _____

Date _____

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Infiltration area protection - silt fence	lineal foot		$2.00	$0.00
Topsoil - 6" depth, salvage on site	square yard		$4.50	$0.00
Site Formation				
Excavation - 6' depth	square yard		$8.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site - 6' depth	square yard		$10.00	$0.00
Structural Components				
Inlet structure	each		$1,500.00	$0.00
Multi-stage outlet structure	each		$2,500.00	$0.00
Site Restoration				
Sod filter strip	lineal foot		$1.50	$0.00
Soil preparation	square yard		$5.00	$0.00
Seeding	square yard		$0.50	$0.00
Planting - below outlet elevation	square yard		$30.00	$0.00
Mulch	square yard		$2.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Annual Operation and Maintenance				
Replace planting media	square yard		$12.00	$0.00
Debris removal	per visit		$50.00	$0.00
Mow filter strips	per visit		$50.00	$0.00
Sediment removal	per year		$500.00	$0.00
Replace plants	per plant		$5.00	$0.00
Erosion repair	square yard		$75.00	$0.00
Gate / valve operation	per visit		$125.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Infiltration Basin BMPs. To be used for preliminary cost estimation.

STORMWATER POND
COST ESTIMATE WORKSHEET
2005 Prices

Project Title _____

Owner _____

Location _____

Project Number _____

Date _____

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Topsoil - 6" depth, salvage on site	square yard		$4.50	$0.00
Site Formation				
Excavation - 8' depth	square yard		$10.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site - 8' depth	square yard		$10.00	$0.00
Structural Components				
Inlet structure	each		$2,000.00	$0.00
Overflow structure	each		$3,500.00	$0.00
Site Restoration				
Sod - above vegetative bench	square yard		$4.50	$0.00
Soil preparation	square yard		$5.00	$0.00
Seeding - vegetative bench	square yard		$0.50	$0.00
Mulch	square yard		$1.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Annual Operation and Maintenance				
Debris removal	per visit		$100.00	$0.00
Remove invasive plants	per visit		$500.00	$0.00
Replant wetland vegetation	per plant		$10.00	$0.00
Repair erosion	square yard		$75.00	$0.00
Sediment removal and disposal	cubic yard		$10.00	$0.00
Mow	per visit		$150.00	$0.00
Gate / valve operation	per visit		$125.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Stormwater Ponds BMPs. To be used for preliminary cost estimation.

STORMWATER WETLAND
COST ESTIMATE WORKSHEET
2005 Prices

Project Title _____

Owner _____

Location _____

Project Number _____

Date _____

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Topsoil - 6" depth, salvage on site	square yard		$4.50	$0.00
Site Formation				
Excavation - deepwater zone - 4' average depth	square yard		$5.00	$0.00
Excavation - marsh zone - 1' average depth	square yard		$1.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site - 5' depth	square yard		$5.00	$0.00
Structural Components				
Inlet structure	each		$2,000.00	$0.00
Outlet structure	each		$3,500.00	$0.00
Site Restoration				
Sod - above vegetative bench	square yard		$4.50	$0.00
Soil preparation	square yard		$25.00	$0.00
Seeding - vegetative bench	square yard		$0.50	$0.00
Planting	square yard		$30.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Annual Operation and Maintenance				
Debris removal	per visit		$100.00	$0.00
Remove invasive plants	per visit		$500.00	$0.00
Replant wetland vegetation	per plant		$10.00	$0.00
Repair erosion	square yard		$75.00	$0.00
Sediment removal and disposal	cubic yard		$10.00	$0.00
Mow	per visit		$150.00	$0.00
Gate / valve operation	per visit		$125.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Constructed Wetlands BMPs. To be used for preliminary cost estimation.

SURFACE SAND FILTER
COST ESTIMATE WORKSHEET
2005 Prices

Project Title _____

Owner _____

Location _____

Project Number _____

Date _____

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Topsoil - 6" depth, salvage on site	square yard		$4.50	$0.00
Site Formation				
Excavation - 6' depth	square yard		$8.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site - 6' depth	square yard		$10.00	$0.00
Structural Components				
Underdrain - with pea gravel and geotextile	square yard		$400.00	$0.00
Inlet structure	each		$1,500.00	$0.00
Sand filter media - 18" depth	square yard		$15.00	$0.00
Outlet structure	each		$3,000.00	$0.00
Site Restoration				
Sod filter strip	lineal foot		$1.50	$0.00
Soil preparation	square yard		$5.00	$0.00
Seeding	square yard		$0.50	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Annual Operation and Maintenance				
Debris removal	per visit		$50.00	$0.00
Mowing	per visit		$150.00	$0.00
Sediment removal	per year		$500.00	$0.00
Gate / valve operation	per visiit		$125.00	$0.00
Erosion repair	square yard		$75.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Media Filtration BMPs. To be used for preliminary cost estimation.



Appendix G

Northwest Area (NWA)
Inver Grove Heights Stormwater Manual

Appendix G

Contents

I. NWA Planned Unit Development Overlay District..... 3
II. MPCA Permit..... 19

I. NWA Planned Unit Development Overlay District

Subd 39. Northwest Area Planned Unit Development Overlay District.

A. Findings. The City of Inver Grove Heights finds that the Northwest Area of the community presents unique development challenges and opportunities. Its varied physical topography, areas of extensive tree cover and numerous landlocked, defined wetland basins not only are valued natural features, but also would likely increase the costs for storm sewer infrastructure if a traditional stormwater management plan were implemented. The Northwest Quadrant Study (prepared by Hoisington Koegler Group, 2001) and Northwest Quadrant Hydrologic & Hydraulic Analysis (prepared by Emmons & Olivier Resources, 2004) indicate that alternative land planning, engineering and development practices may be more cost effective in addressing infrastructure needs and meeting the City's Comprehensive Plan goal of preserving unique natural areas/open space.

B. Purpose and Intent. The Northwest Area Planned Unit Development Overlay District is established for the purposes of regulating development in a manner which is consistent with the City's Comprehensive Plan while creating a cost-efficient storm sewer system. In accordance with the City's Comprehensive Plan and the Northwest Quadrant Study: City of Inver Grove Heights and South Robert Trail Neighborhood Association (prepared by Hoisington Koegler Group in 2001), the Northwest Area Planned Unit Development Overlay District will encourage development which provides diverse housing styles, incorporates natural features as integral elements, promotes cluster development practices which preserve significant natural features by concentrating building locations, fosters pedestrian connections and uses on-site retention of stormwater in existing landlocked basins preserved in open space areas. The provisions of the Northwest Area Planned Unit Development Overlay District will also reduce the amount of stormwater runoff from the district through minimizing impervious surface coverage. Provisions will also maximize the ability to infiltrate stormwater without piping to a remote outlet (i.e. Mississippi River) through the preservation of natural areas for infiltration. The Northwest Area Planned Unit Development Overlay District will have clustered housing and will permit mixtures of housing types to encourage greater preservation of natural areas/open space as long as requirements for stormwater management features are met.

All development within the Northwest Area Planned Unit Development Overlay District shall be by Planned Unit development according to: 1) the platting procedures as established in the City's Subdivision Ordinance (Sections 510.05, 510.07, 510.09, 510.10 and 510.11); 2) the Planned Unit Development procedures established in the City's Zoning Ordinance (Section 515.80, Subdivision 28); and 3) the provisions found in this Section of the City Code, Section 515.80, Subdivision 39. If there are any conflicts in these standards, the most restrictive standard shall apply, unless specifically approved otherwise by the City Council.

C. Property without Municipal Sewer and Water. The Northwest Area Planned Unit Development Overlay District does not have municipal sewer or water available as of the date of adoption of this Section 515.80, Subd. 39. As municipal sewer and water become available to properties in the Northwest Area Planned Unit Development Overlay District, development shall be allowed subject to this Section 515.80, Subd. 39. Until such time as municipal sewer and water become available and final Planned Unit Development plans are approved by the City for the specific property, lots are required to have a minimum size of 10 acres. All lots of record in existence prior to November 28, 1988 shall be exempt from the 10-acre minimum lot area requirement. Instead, all such lots of record shall have minimum lot sizes as specified by the lot size regulations for the underlying zoning district within which the lot of record is located.

The minimum lot size of 10 acres is established for properties that do not yet have municipal sewer and water in order to:

1. Prevent parcelization of land before municipal sewer and water become available.
2. Reduce the density of residential development in areas lying outside the area of the City where municipal utilities are available in order to prevent the untimely, non-cost effective extension of City utilities due to the failure of on-site septic systems.
3. Prevent adverse effects upon the environment due to the failure of on-site waste disposal systems.
4. Promote the provision of residential lot areas that more easily facilitate re-subdivision when City utilities become available, particularly in those areas where utility extensions may occur in the reasonably foreseeable future.
5. Lessen the potential demand in the rural areas for City services such as police and fire protection and street and park services.
6. Channel development of significant tax base into the areas of the City that have municipal sewer.

D. Subdivision of Property not served by Municipal Sewer and Water. Subdivision of property in the Northwest Area Planned Unit Development Overlay District that is not served by municipal sewer and water is prohibited, except as provided for in this Subsection D. Limited subdivision will be allowed without municipal sewer and water if the subdivision meets all of the following standards:

1. The subdivision shall be memorialized through platting. No Waiver of Plat procedure shall be allowed.
2. A property must have a minimum of 20 acres (excluding right of way) in order to be subdivided.
3. The subdivision shall result in a density no greater than one home per 10 acres of land (excluding right of way).
4. The resulting plat shall include buildable lots of a size no less than 1.0 acres and no greater than 1.5 acres. The remainder of the property shall be platted as an outlot, or outlots. The outlot(s) shall be considered unbuildable, and no further subdivision of the outlot(s) shall be allowed until such time as municipal sewer and water become available to the property. When municipal sewer and water become available to the property, the outlot(s) may develop, but will be required to develop according to: 1) the platting procedures as established in the City's Subdivision Ordinance (Sections 510.05, 510.07, 510.09, 510.10 and 510.11); 2) the Planned Unit Development procedures established in the City's Zoning Ordinance (Section 515.80, Subdivision 28); and 3) the provisions found in this Section of the City Code, Section 515.80, Subdivision 39.

Planned Unit Development procedures and standards shall not apply to subdivisions that are eligible for subdivision according to the provision of this Subsection D.

E. District Boundaries and Applicability. The Northwest Area Planned Unit Development Overlay District, further defined in this Section 515.80, Subd. 39 is hereby established as a part of the Zoning Ordinance of the City of Inver Grove Heights (Inver Grove Heights City Code, Section 515). The Northwest Area Planned Unit Development Overlay District shall be an overlay district such that any parcel lying in the overlay district shall also lie within one or more of the underlying zoning districts. Regulations and procedures set forth in underlying zoning districts shall apply unless specifically addressed in this Section 515.80, Subdivision 39 or if determined by the City Council to be inconsistent with the purpose and intent outlined in Subsection B of this Section 515.80, Subdivision 39 and approved by the City Council as part of the final Planned Unit Development plans. For purposes of determining the application of this Section 515.80, Subd. 39, the boundaries of the Northwest Area Planned Unit Development Overlay District shall be established and shown on the Official Zoning Map of the City of Inver Grove Heights, on file in the office of the City Clerk. Said map and the boundaries shown thereon are hereby incorporated herein by reference with the

same force and effect as if fully set forth herein.

F. Definitions. [NOTE: the definitions in this section will be incorporated into the definition section for the entire zoning code. But they are included here for the draft ordinance] The provisions of this Section 515.80, Subd. 39 shall be interpreted in accordance with the definitions identified in Section 515.30, Subd. 2 in addition to the following:

1. Homeowners association - an incorporated nonprofit organization operating under recorded land agreements through which (a) each lot and/or homeowner is automatically a member; (b) each lot is automatically subject to a charge for a proportionate share of the expenses for the organization's activities, such as maintaining a common property; and (c) the charge, if unpaid, becomes a lien against the property.

2. Infiltration basins/trenches - an area that allows stormwater rainfall/runoff to gradually seep into the ground.

3. Infiltration raingardens - landscaped garden designed and planted to receive and infiltrate stormwater runoff.

4. Low impact development (LID) - an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts to land, water, and air by integrating site design and planning techniques that conserve natural systems and hydrologic functions of the site.

5. Natural area/open space - any unimproved land or water that is set aside, dedicated, designated or reserved for perpetuity.

6. Natural plant materials - use of vegetation which occurred naturally prior to development, preferably native plants.

7. Net developable area – the area of a property remaining after excluding those portions that are either: a) encumbered by right of way for arterial roads as defined in the Inver Grove Heights Comprehensive Plan; or b) lying below the ordinary high water level of public waters as identified in the Shoreland Overlay District (see City Code Section 515.80, Subd. 30); or c) lying within the boundaries of wetlands delineated according to the Minnesota Wetland Conservation Act; or d) bluffs in Shoreland Overlay Districts abutting public waters; or e) land to be dedicated to the City of Inver Grove Heights for public park/recreation area purposes.

8. Bioretention - a landscaped area typically located at the edge of parking lots and may have an underdrain present where stormwater runoff is directed for filtering and discharge to other stormwater features.

9. Steep slopes - a predevelopment grade of 25% or more for a horizontal distance of 50 feet or more.

10. Stormwater management features - a feature used to treat, detain, and/or retain stormwater.

11. Stormwater management plans - document which identifies stormwater management features to be used in a development, how they will be designed and constructed, how and what type of maintenance to be completed, when and what type of inspections will be necessary, and who will be responsible for ongoing maintenance and inspections.

G. Planned Unit Development. All development in the Northwest Area Planned Unit Development (PUD) Overlay District shall be pursuant to an approved final PUD plan set, except as allowed in Subsection D above. The procedures and regulations set forth in Section 515.80, Subd. 28 (Planned Unit Development) shall apply unless specifically addressed in the following subsections. The following subsections are hereby deemed to be requirements for all PUDs in the Northwest Area Planned Unit Development Overlay District unless otherwise approved by the City Council.

1. Minimum Area for Planned Unit Development. There is no minimum required site size for a PUD in the Northwest Area Planned Unit Development Overlay District. However, all land in the PUD must be contiguous unless specifically approved otherwise by the City Council.

2. Ownership. The tract of land may be held in single and separate ownership or in multiple ownerships. However, when a tract is held in multiple ownerships, it shall be planned as a single entity with common authority and common responsibility as demonstrated through all property owners being signatories on the PUD application.

3. Bulk Standards.

   a. All setbacks on the perimeter of a PUD must conform to the setbacks of the underlying zoning district.

   b. Except as provided in Section 515.80, Subd. 39 G.3.a above, property in a PUD shall conform to the bulk standards established in the following table:

Use (Correlates with underlying zoning district as specified below)	Density[1]		Front Yard Setbacks[2]		Side Yard	Impervious Surface Coverage	Building Coverage	Building Height
	Minimum	Maximum	Min.	Max.	Min. Principal Structure Separation[3]	Maximum per lot	Maximum per lot	Maximum per lot
Residential								
Single Family (Correlates with R-1C)	2 units/ac.	4 units/ac.	20 ft.	30 ft.	20 ft.	25%	None	35 ft.
Two Family/ Twinhome (Correlates with R-2)	3 units/ac.	8 units/ac.	20 ft.	30 ft.	20 ft.	30%	None	35 ft.
Multi-Family (3-4 units) (Correlates with R-3A)	5 units/ac.	12 units/ac.	20 ft.	30 ft.	20 ft.	35%	20%	35 ft.
Multi-Family (4 to 7 units) (Correlates with R-3B)	8 units/ac.	15 units/ac.	20 ft.	30 ft.	20 ft.	55%	20%	56 ft
Multi-Family (7+ units) (Correlates with R-3C)	12 units/ ac.	NA	20 ft.	30 ft.	20 ft.	65%	20%	70 ft.
Commercial								
Retail (Correlates with B-2, B-3, or B-4)	0.25 FAR	0.35 FAR	10 ft	30 ft.	20 ft.	70%	25%	50 ft.
Neighborhood Office (Correlates with B-1)	0.25 FAR	0.5 FAR	10 ft.	30 ft.	20 ft.	70%	25%	50 ft.
Office PUD and other office (Correlates with B-1 or Office PUD)	0.25 FAR	0.5 FAR	30 ft.	40 ft.	20 ft.	70%	30%	100 ft.
Industrial (Correlates with I-1, 1-2, or IOP)	0.25 FAR	0.35 FAR	30 ft.	40 ft.	20 ft.	70%	30%	60 ft.
Mixed Use	As defined through the Final PUD plans as approved by the City Council							

[1] Density is calculated as per Section G.7.c. Procedures, which is based upon net developable area. However, in no instance may the density exceed that established for the property in the Inver Grove Heights Comprehensive Plan, and such density limits are incorporated by reference and hereby made a part of this Section 515.80, Subdivision 39.

[2] Rear yard setbacks shall follow the underlying zoning district setback standards

[3] In no instance may a building lie within an area of the lot encumbered by an easement.

4. Natural Area/Open Space

   a. An amount of land equal to at least 20% of the net developable area within the PUD shall be preserved as natural area/open space, which may include greenways as shown in the City of Inver Grove Heights Natural Resources Inventory and Management Plan (Bonestroo Rosene Anderlik & Associates, 2004).

b. Natural Area/Open Space shall be designated in the following priority order:

(i). The first priority is to protect slopes of 25% or greater in those subwatersheds that have a significant portion of their drainage area covered in slopes of 25% or greater, as follows: (insert list of identified subwatersheds).

(ii). The second priority is to incorporate public trails or public open space designated in the Comprehensive Plan. This would be in addition to any land that would be used to satisfy the public park dedication requirement found in the City's Subdivision Ordinance (Section 510).

(iii). The third priority for natural area/open space designation is the protection of natural features such as slopes of 25% or greater, and environmentally sensitive areas and scenic features of the site identified as Manage 1 or 2 resources or priority sites in the City of Inver Grove Heights Natural Resource Inventory and Management Plan for the Northwest Expansion Area (Bonestroo Rosene Anderlik & Associates, 2004).

(iv). The fourth priority is to create natural area/open spaces in and around neighborhoods. This priority is satisfied by providing continuity of adjacent natural area/open space corridors or parkways; network of interconnected natural area/open space corridors; or buffers between incompatible or conflicting land uses.

c. At least 75% of the natural area/open space shall be contiguous with no portion less than 100 feet wide, unless otherwise approved by the City Council.

d. At least 50% of the natural area/open space shall be maintained in a natural, undisturbed condition with natural plant materials and shall not be graded or improved with any building, structure or other impervious surface except: 1) public utilities; 2) limited access in the form of a paved walking or hiker/biker path, the total impervious area of which shall not be more than 2% of the total natural area/open space; and 3) unless otherwise approved by the City Council.

e. The remaining 50% of designated natural area/open space may be used for passive or active recreation or the location of stormwater management features. If used for active recreation, impervious cover shall not exceed 5% of the remaining area.

f. The entire area set aside for natural area/open space shall be maintained in perpetuity. This restriction shall run with the land and be binding on successors and assigns of land owner.

g. The boundaries of designated natural area/open space and recreation areas shall be clearly delineated on the approved final PUD plans. These areas shall be delineated in the field with signage approved by the City of Inver Grove Heights.

h. The designated natural area/open space may be owned and managed by one or more of the following:

(i). Property owner, provided either: 1) the deed to each lot includes a proportionate share of the natural area/open space or common facilities; or 2) an easement for the natural area/open space is provided for the benefit of the lots in the subdivision.

(ii). Homeowners association, provided all of the following conditions are met:

(a). The homeowner's association must be established prior to filing of any plats.

(b). Membership must be mandatory for each owner and any successive buyer.

(c). The association must be responsible for liability insurance, local taxes and maintenance of the natural area/open space.

(d). Landowners must pay their pro rata share of the cost and the assessment levied by the association that can become a lien on the property in accordance with Minnesota Statues.

(e). The association must be able to adjust the assessment to meet changed needs.

(iii). Third-party (non-profit) organization whose primary purpose is to hold or manage the natural area/open space; subject to a reversionary clause in the event of dissolution of the non-profit organization.

(iv). Dedicated to the City of Inver Grove Heights, if the City Council determines there is a demonstrated public need.

i. The maintenance of the natural area/open space shall be the responsibility of one of the entities identified above in Section 515.80, Subd. 39 G.4.h. Public stormwater or utility improvements may be located within a portion of the natural area/open space, as specified above in Section 515.80, Subd. 39 G.4.d and e, in which case the City of Inver Grove Heights shall be responsible for maintenance of that portion of the natural area/open space.

j. Authorized representatives of the City of Inver Grove Heights may conduct inspections at any reasonable time to ensure proper maintenance of such areas and/or to respond to citizen complaints.

k. The legal instrument creating the restrictions, easements and covenants in the natural area/open space shall be subject to approval by the City, and the instrument recorded with Dakota County shall state that the restrictions, easements and covenants shall not be terminated or altered without the written consent of the City.

l. If the property to be subdivided contains natural resources identified as Manage 1 or 2 resources or priority sites in the City of Inver Grove Heights Natural Resource Inventory and Management Plan for the Northwest Expansion Area (Bonestroo Rosene Anderlik & Associates, 2004), the City Council may at its discretion require the Manage 1 or 2 resource or priority site to be encumbered with a conservation easement to the public. Said conservation easement would include at least the following provisions:

(i). No vegetation shall be removed or mowed from the easement area, except for invasive vegetation species when removed according to a plan approved by the City.

(ii). No private structures may be placed within the easement area

(iii). No grading shall be allowed except as approved with the final Planned Unit Development Plan, or subsequent City approved amendments thereto.

(iv). No gardening shall be permitted within the easement area.

5. <u>Allowed Uses</u>

a. Except those uses identified in subpart c. below as “interim uses”, all permitted, conditional, and accessory uses as defined, regulated and administered for the underlying zoning districts shall continue and remain in effect within the Northwest Area Planned Unit Development Overlay District. If a final PUD plan is approved by the City Council, the underlying zoning for the subject property shall be amended, though the overlay district shall remain the Northwest Area Overlay District. The permitted uses shall then be those found in the amended underlying zoning district. Except that PUD developments in the Northwest Area Planned Unit Development Overlay District are allowed to have an increased mixture of housing types provided that the provisions of this Section 515.80, Subd. 39 are met. The table below identifies

which uses are permitted and the maximum percentage of the total development units which can be of that housing type. The total number and location of housing units and housing types for a specific property shall be established by the City Council at the time of final PUD plan approval for that specific property. Moreover, the location of housing units not normally associated with the amended underlying zoning district may not be altered from that approved with the final PUD plan, nor may the number of housing units not normally associated with the amended underlying zoning district be increased over the number approved with the final PUD plan. For example, if the amended underlying zoning district is R-1C, and the City Council approves housing types other than permitted in the R-1C zoning district, those housing types not permitted in the R-1C zoning district shall be limited in terms of number and location to those approved by the City Council with the final PUD plan.

Uses	Zoning District				
	R-1C	R-2	R-3A, or B	R-3C	MU
Single Family Dwellings	100%	100%	10%	10%	10%
Twinhomes/Two-Family Dwellings	30%	100%	30%	10%	15%
Multiple dwelling unit building (7 or fewer units)	10%	30%	100%	40%	100%
Multiple dwelling unit building (7 + units)	0%	0%	50%	100%	100%

Note: The % in the above table represents the total percent of units allowed by unit type or "use" in each district. For example, in the R-1C district, up to 30% of the total units in the proposed PUD may be twinhomes or two-family dwellings, or alternatively, the entire PUD could consist of all (100%) single family housing.

b. **Multiple dwelling units (including townhomes) permitted as of right.** Within the overlay district, where multiple dwelling units are indicated as permitted (see above table), they shall be permitted as of right provided they follow the performance standards as specified in Section 515.90 (specifically those in subd. 26 and 27), those specified in this Section 515.80, Subd. 39, and the approved final PUD plans.

c. **Interim Uses.**

(i). Purpose and Intent: The Northwest Area Planned Unit Development Overlay District is envisioned to develop at urban development densities over the next 20 or more years. The premature development of this area in an estate type development pattern (large residential lots with sizes of 2 ½ to 5 acres on private sanitary sewer systems and private wells) presents challenges to the efficiency and coherency of future development. In addition to rural development patterns, rural uses (boarding of horses, agriculture, etc.) that are incompatible with urban development will also pose challenges to the orderly development of the Northwest Area Planned Unit Development Overlay District. Consequently, it is the purpose of this subsection of the City Code to establish interim uses that are appropriate to the Northwest Area Planned Unit Development Overlay District while preserving the reasonable use of private property.

(ii).Uses Requiring an Interim Use Permit: Regardless whether the following uses are considered permitted uses in the underlying A, Agricultural Zoning District, the following uses shall be considered interim uses in the Northwest Area Planned Unit Development Overlay District and shall require approval of an Interim Use Permit by the City Council pursuant to the procedures established in Section 515.80, Subd. 38 of the City Code:

(a) Agriculture buildings
(b) Commercial greenhouse / nurseries
(c) Commercial horse stables
(d) Commercial kennels

6. Stormwater Management

a. **Design**. All development in the Northwest Area Planned Unit Development Overlay District shall be designed such that stormwater runoff is managed on-site within the planned unit development to match predevelopment runoff, as demonstrated by matching pre and post development runoff volume for the 5-year, 24-hour event. The stormwater system shall also have managed overflows to the regional system of natural depressions such that the stormwater rainfall/runoff for a 100 year event is safely transported. Contingencies for emergency overflows at least one foot below the lowest structure shall be provided.

(i). For any proposed PUD development the developer shall submit a stormwater management plan which contains supporting computations, drawings and sufficient information describing the manner, location and type of measures in which stormwater runoff will be managed from all phases of the PUD development. The developer shall also submit soil borings for the site including proposed stormwater infiltration areas.

(ii). The stormwater management plan shall be prepared by an individual whose qualifications are acceptable to the City of Inver Grove Heights. The City of Inver Grove Heights may require that the design be prepared by a professional licensed in the State of Minnesota, as necessary to protect the public or the environment.

(iii). Stormwater management plans shall use one or more of the following features to address onsite stormwater management. These measures shall be designed in accordance with the most recent version of the City of Inver Grove Heights Stormwater Manual. The performance criteria specified in the City of Inver Grove Heights Stormwater Manual shall be considered when selecting the appropriate management features such as:

- Infiltration raingardens (encumbered by public easement and maintained by the City of Inver Grove Heights)
- Vegetated swales (encumbered by public or private easement and maintained by the City of Inver Grove Heights or private parties, as approved by the City together with the final PUD plans and stormwater management plan.)
- Parking lot bioretention (encumbered by a private easement if found necessary by the City and maintained by private parties.)
- Infiltration basins/trenches (encumbered by public or private easement and maintained by the City of Inver Grove Heights or private parties, as approved by the City together with the final PUD plans and stormwater management plan.)
- Disconnection of impervious surfaces, e.g. diverted roof leaders, rain barrels, permeable pavement (These features are to be encumbered by a private easement if found necessary by the City and maintained by private parties.)
- Green roofs (Private maintenance)
- Other Low Impact Development (LID) techniques

(iv). Stormwater management plans will stage construction and specifically address temporary erosion and sediment control measures to preserve the infiltration capacity of proposed onsite and regional stormwater management features to ensure that such features are not impaired at conclusion of construction.

(v). Stormwater easements over those stormwater management features that the City chooses to maintain shall be provided by the property owner for access, facility inspections and public maintenance. The easements shall be fully executed and submitted to the City of Inver Grove Heights prior to the release of the final plat from City offices for recording by Dakota County.

(vi). Covenants and/or maintenance agreements found acceptable to the City

relating to all stormwater management features not to be maintained by the City shall be provided by the property owner. The covenants and/or maintenance agreements shall be fully executed and submitted to the City of Inver Grove Heights prior to the release of the final plat from City offices for recording by Dakota County.

(vii) The legal instrument creating the restrictions, easements and covenants in the natural area/open space shall be subject to approval by the City, and the instrument recorded with Dakota County shall state that the restrictions, easements and covenants shall not be terminated or altered without the written consent of the City.

(viii). Final design of the stormwater management plan shall be approved by the Inver Grove Heights City Council and shall be filed in the chain of title for each property that lies within the Planned Unit Development. A condition of approval shall be that the landowner shall enter into a license contract with the City allowing authorized representatives from the City of Inver Grove Heights to conduct inspections on a regular basis at any reasonable time to assure the safe and proper functioning of the private stormwater management features and/or to respond to citizen concerns. The license contract shall also permit authorized representatives of the City to enter upon the private property for the purpose of correcting or maintaining any private stormwater management feature approved as a part of the stormwater management plan if after proper and reasonable notice by the City to the landowner the landowner has not corrected or maintained the stormwater management feature to the standards established in the approved stormwater management plan, the most recent version of the City of Inver Grove Heights Stormwater Manual and/or this Section 515.80, Subd. 30. Moreover, the license contract shall permit the City to certify the costs of the maintenance/correction to the taxes for the subject private property.

b. **Ownership**

(i). The boundaries of stormwater management features shall be clearly delineated on all plans, including final PUD plans, preliminary plats and final plats.

(ii). The designated stormwater management features may be owned by one or more of the following:

(a). Property owner, provided the deed to each lot includes a proportionate share of the stormwater management features.

(b). Homeowners association, provided all of the following conditions are met:

(1) The homeowner's association must be established prior to any sale.

(2) Membership must be mandatory for each owner and any successive buyer.

(3) The association must be responsible for liability insurance, local taxes and maintenance of the stormwater management features.

(4) Landowners must pay their pro rata share of the cost and the assessment levied by the association that can become a lien on the property in accordance with Minnesota Statues.

(5) The association must be able to adjust the assessment to meet changed needs.

(c). Third-party (non-profit) organization whose primary purpose is to hold or manage the stormwater management features; subject to a reversionary clause in the event of dissolution of the non-profit organization.

(d). The City will accept ownership by easement of the stormwater management features including rainwater gardens when the features serve as a part of

the larger regional or neighborhood stormwater management needs as defined by the Northwest Area Hydrologic & Hydraulic Analysis completed by Emmons & Olivier Resources in 2002 or the Northwest Area Alternative Urban Areawide Review prepared by Bonestroo Rosene and Anderlik & Associates in 2005. The City will not accept ownership of such features as downspouts, cisterns, green roofs, parking lot remediation or other such systems or features interior to the parcel.

c. **Maintenance**

(i). All stormwater features encumbered by public easements as described above in Section 515.80, Subd. 39 G.6.a.(v) shall be maintained by the City of Inver Grove Heights according to the measures outlined in the most recent version of the City of Inver Grove Heights Stormwater Manual.

(ii). All stormwater features that are not encumbered by public easements as described above in Section 515.80, Subd. 39 G.6.a.(v) shall be maintained according to the covenants and/or maintenance agreements approved by the City pursuant to Section 515.80, Subd. 39 G.6.a.(vi) above, the stormwater management plan approved by the City with the Planned Unit Development and the development contract approved by the City together with the Planned Unit Development plans.

d. **Inspections**

(i). Authorized representatives of the City of Inver Grove Heights may conduct inspections at reasonable times throughout the construction process to meet the specifications in the Stormwater Design Manual and the stormwater management plan approved by the City together with the Planned Unit Development plans.

(ii). Authorized representatives from the City of Inver Grove Heights may conduct inspections on a regular basis at any reasonable time to assure the safe and proper functioning of the features and/or to respond to citizen concerns.

e. **Stormwater Manual** The City of Inver Grove Heights Stormwater Manual for the Northwest Area is hereby incorporated herein by reference with the same force and effect as if full set forth herein.

7. Procedures

a. **Sketch Plan**. Preparation of a sketch plan by the developer is strongly encouraged. Given the site design complexities of the Northwest Area Planned Unit Development Overlay District, a sketch plan should be prepared and submitted for each development. Without a thoroughly prepared sketch plan, the likelihood increases that the preliminary development plan application will be found inadequate by the City. The sketch plan should be prepared following the submittal requirements outlined in Section 510.07, Subd. 1 of the Subdivision Ordinance. In addition, the sketch plan should include the following elements: 1) a preliminary stormwater management concept should be provided in outline format identifying desired techniques for the development proposal based upon the City of Inver Grove Heights Stormwater Manual; 2) identification of the natural resources as included within the City of Inver Grove Heights Natural Resource Inventory and Management Plan for the Northwest Expansion Area (Bonestroo Rosene Anderlik & Associates, 2004); 3) a conceptual yield plan as described below in Section 515.80, Subd. 39 G.7.c; and 4) a conceptual scaled natural area/open space plan identifying all natural area/open spaces as required above in Section 515.80, Subd. 39 G.4. The sketch plan should be prepared and presented to City Staff 30 days prior to

submittal of the preliminary PUD plan.

b. **Preliminary Development Plan**. A Preliminary Development Plan shall be prepared and submitted by the developer. It shall include: 1) a preliminary plat prepared pursuant to Section 510.07, Subd. 2; 2) a preliminary PUD development plan prepared pursuant to Section 515.80, Subd. 28, Subsection K; and 3) a stormwater management plan consistent with the City of Inver Grove Heights Stormwater Manual and consistent with the stipulations provided in this Section 515.80, Subd. 39, G.6.

c. **Yield Plan Required**. A "yield plan" shall be prepared by the developer as part of the preliminary development plan for every residential project. The yield plan shall determine the total number of units that could be developed on the site according to the underlying zoning district regulations. The total unit count determined through the yield plan shall then become the total number of units permitted under the Northwest Area Planned Unit Development Overlay District regulations.

Calculation of the total number of permitted residential units shall be determined in the following manner:

(i). Determine the total net developable area (in acres) per the definition of net developable area as found in Section 515.80, Subd. 39 G.7.
(ii). Divide the developable area determined in step (i) above by the minimum lot area as established for the applicable underlying zoning district and found in City Code Section 515.80, Subdivisions 8-9 and 11-13. The result is the total number of units that could be developed on the site in the underlying zoning district.
(iii). The total number of units determined in step (ii) above shall be the total number of units permitted under this Northwest Area Planned Unit Development Overlay District section of the City Code.

d. **Final Development Plan**. A final development plan shall be prepared and submitted by the developer. It shall include: 1) a final plat prepared pursuant to Section 510.07, Subd. 3; 2) a final PUD development plan prepared pursuant to Section 515.80, Subd. 28, Subsection L; and 3) the final development plans in the Northwest Area Planned Unit Development Overlay District shall follow the procedures outlines in Section 430.11 Stormwater Management. No physical alteration or improvement of the property may commence until after the final development plan and development contract are approved by the City Council, except that site grading may begin earlier if the City Council approves a land alteration permit for the grading.

H. Performance Standards. Developments shall follow the standards of Section 515.90 unless otherwise addressed in this Subsection.

1. Site Landscaping Within the Northwest Area Planned Unit Development Overlay District, the use of natural plant materials for landscaping is encouraged in common areas. Areas preserved with natural landscaping shall be maintained in accordance with local and state regulations governing control of noxious weeds. Mass grading for landscaping areas should be avoided to reduce compaction of natural area/open space areas.

2. Off-Street Parking and Loading

a. **Joint Parking.** Joint Parking arrangements are encouraged in the Northwest Area Planned Unit Development Overlay District.

b. **Off-Site or Remote Parking Facilities**. Within the Northwest Area Planned Unit

Development Overlay District remote parking is permitted so long as it is within reasonable walking distance to the principal use and that it does not require crossing major physical barriers such as freeways, four lane arterials, water bodies or other non-pedestrian friendly features. Reasonable walking distance is considered no more than a 1/8th mile or a five minute walk.

c. **Parking Surfaces**. Parking surfaces may be made of pervious materials such as pavers, pervious asphalt or concrete or other technology as identified in the City of Inver Grove Heights_Stormwater Manual. These areas shall still be considered as impervious surfaces for stormwater calculations; however, 50% of pervious pavement areas may be credited toward the 20% natural area/open space requirements (see Section 515.80, Subd. 39 G.4.a). Long term redevelopment and maintenance must preserve the pervious pavement surface.

d. **Parking Lot Curbing.** Curbs shall be designed to meet the standards set forth in the City of Inver Grove Heights Stormwater Manual so as to insure safety and best management of stormwater. Generally curbs shall either be flat or have breaks at regular intervals to convey runoff into the stormwater system unless a stormwater management plan demonstrates that another curbing system meets stormwater management performance objectives.

e. **Minimum and Maximum Number of Permitted Off-Street Parking Spaces**. City Code Section 515.90 Subdivision 21 D.9. establishes a minimum number of required off-street parking spaces for various land uses. With the exception of Single Family Dwellings and Two-Family Dwellings, this section 515.80, Subd. 39 re-establishes the minimum required off-street parking spaces and establishes a maximum allowed number of parking spaces as well.

   (i). The minimum required off street parking spaces shall be no less than 75% of the minimum parking required by City Code Section 515.90 Subdivision 21 D. 9.
   (ii). The maximum allowed off street parking spaces shall be no more than 100% of the minimum parking required by City Code Section 515.90 Subdivision 21 D. 9.
   (iii). The maximum allowed off street parking identified above, may be exceeded by no more than 10% of the total number of parking spaces provided that at least 50% of the total parking lot surface area is paved with a pervious material consistent with techniques identified in the Stormwater Design Manual or 50% of the parking spaces are in a deck structure or underground.

f. **Parking for Multi-Family (including townhomes) Residential and Mixed Use**. 50% of total parking required for Multi-Family and Mixed Use development shall be underground parking, tuck-under parking or structured parking within or under the principal structure. The intent of this regulation is to minimize impervious surface that would result from surface parking lots.

g. **Alternative Paving for Overflow Parking.** Pervious paving materials shall/may [need to determine which] be used for that portion of parking over the minimum required off-street parking spaces.

h. **Proof of Parking.** Developments that can accommodate parking allotments less than the minimum parking spaces required may do so provided that the final PUD plan includes the identification of area dedicated for future parking needs to satisfy the minimum parking needs.

i. **On-Street Parking Provision.** Where on-street parking is available, parking spaces that are adjacent to the lot frontage of the subject use may be counted towards the off-street parking requirement.

j. **Parking Lot Landscaping**. Surface parking lots in excess of 100 spaces shall provide landscaped islands between double loaded rows of parking. Such landscaped islands shall also serve as a stormwater cell and shall be designed according to the guidelines established in the City of Inver Grove Heights Stormwater Manual.

3. Driveways

a. Driveway widths for single-family detached residential dwellings, two family and twin home dwellings shall be no more than 20 feet. In all other cases it shall be no more than 32 feet. Where additional hard surface is desired such as an additional parking space near the garage or where a turn around/guest parking space is desired it must be of a permanent pervious surface such as brick pavers, pervious concrete/asphalt or other technique as approved through the City of Inver Grove Heights Stormwater Manual.

b. Shared driveways are encouraged within the Northwest Area Planned Unit Development Overlay District to reduce impervious surface coverage. No more than two parcels may be served by a shared driveway, unless otherwise approved by the City Council. Shared driveways shall extend from a public or private street and shall not connect to any other existing or planned public or private street. Appropriate cross easements and maintenance agreements are required with submittal of final PUD plan and shall be recorded with the final plat.

c. Single-family residential driveways are encouraged to be constructed of pervious materials such as pavers, pervious concrete or pervious asphalt.

4. Miscellaneous

a. All residential downspouts and sump pumps shall discharge to cisterns and/or permeable surfaces.
b. All non-residential downspouts and sump pumps shall discharge to permeable surfaces if reasonably possible.

I. Subdivision Ordinance Regulations. The standards and regulations identified in Section 510 shall be followed except when standards are identified in this section.

1. Streets

a. Streets designed as collectors or arterials shall be designed based on City of Inver Grove Height standards.

b. Local streets may take the form of a two-way street, a pair of one-way streets on either side of a landscaped median, or a one-way loop street.

c. Local Streets shall have the following design standards

(i). Right-of-Way widths shall be between 50 and 60 feet as dictated by the location of stormwater features.
(ii). Local public streets shall have a 28 foot paved width in addition to a sidewalk or trail on one side of the street. This street dimension shall restrict parking to only

one side of the street.

(iii). Local private streets with a 24 foot width shall be acceptable with no parking on either side. Homes fronting on these streets shall demonstrate where parking is to be accommodated on site discouraging parking on curbs or in boulevards but consistent with the other provisions of this ordinance.

d. The developer/applicant must demonstrate that access to the development has the capacity to handle traffic generated by the proposed project and will not endanger the safety of the general public.

e. Cul-de-sac dead end streets are discouraged. Cul-de-sac dead end streets, designed to be so permanently shall be provided at the closed end with a turn-around having an outside roadway radius of 35 feet and a street property line (ROW) radius of 50 feet. Cul-de-sacs can be designed with larger diameters provided a landscaped island is included and designed for stormwater storage. Landscaped medians are encouraged to be designed in cul-de-sac bulbs to handle stormwater runoff and provide a place for snow storage during snow season.

f. Where proposed streets will connect with existing streets having differing standards, the street dimension shall be the same as those of the existing connecting street. All street widening shall occur at the nearest intersection.

II. MPCA Permit

GENERAL PERMIT
AUTHORIZATION TO DISCHARGE
STORM WATER ASSOCIATED WITH CONSTRUCTION ACTIVITY
UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION
SYSTEM/STATE DISPOSAL SYSTEM PERMIT PROGRAM

ISSUANCE DATE: August 1, 2003 EXPIRATION DATE: August 1, 2008

In compliance with the provisions of the Clean Water Act, as amended, (33 U.S.C. 1251 et seq.; hereinafter, the "**Act**"), 40 CFR 122, 123, and 124, as amended, et seq.; Minn. Stat. Chs. 115 and 116, as amended, and Minn. R. Ch. 7001:

This permit regulates the discharges of **storm water** to the **waters of the state** of Minnesota associated with **construction activity**. This permit covers the **storm water** discharges identified in Part I.A. of this permit. The limitations on permit coverage are identified in Part I.B. of this permit.

This permit requires the development and implementation of a **Storm Water Pollution Prevention Plan (SWPPP)**. No person shall commence **construction activity** covered by Part I.A. until permit coverage under this permit is effective or, if applicable, until the Minnesota Pollution Control Agency (MPCA) has issued an individual NPDES/SDS construction **storm water** permit for the project. The **SWPPP** must be completed prior to submitting any permit application and prior to conducting any **construction activity** by any required **Permittee**.

Unless notified by the MPCA to the contrary, applicants who submit a completed application (including permit fee) in accordance with the requirements of this permit are authorized to discharge **storm water** from construction sites under the terms and conditions of this permit 7, 30, or 90 days after the postmarked date of the completed application as described in Part II.B.

Coverage under this permit will remain in effect until the **owner** has submitted a **Notice of Termination**, regardless of the above expiration date.

Signature: Daniel D Foley as Board Member

for

Minnesota Pollution Control Agency

If you have questions on this permit, including the specific permit requirements, permit reporting or permit compliance status, please contact the appropriate MPCA offices.

Minnesota Pollution Control Agency
Construction Storm Water Program
520 Lafayette Road North
St. Paul, MN 55155-4194
Telephone (651) 297-2274

wq-strm2-51

Table of Contents

Page

I. PERMIT COVERAGE AND LIMITATIONS 3

A. Permit Coverage 3
B. Limitations of Coverage 3

II. SUBMITTING THE APPLICATION 4

A. Prerequisite for Submitting a Permit Application 4
B. Application and Duration of Coverage 4
C. Termination of Coverage 6

III. STORM WATER DISCHARGE DESIGN REQUIREMENTS 7

A. Storm Water Pollution Prevention Plan 7
B. Temporary Sediment Basins 9
C. Permanent Storm Water Management System 10
D. Record Retention 13

IV. CONSTRUCTION ACTIVITY REQUIREMENTS 13

A. Storm Water Pollution Prevention Plan 13
B. Erosion Prevention Practices 13
C. Sediment Control Practices 14
D. Dewatering and Basin Draining 15
E. Inspections and Maintenance 15
F. Pollution Prevention Management Measures 17
G. Final Stabilization 17

V. GENERAL PROVISIONS 18

A. Applicability Criteria 18
B. Response 18
C. Prohibitions 18
D. Transfer of Ownership or Control 18
E. Civil and Criminal Liability 18
F. Severability 19
G. NPDES/SDS Rule Standard Conditions 19
H. Inspection and Entry 19

APPENDIX A 19

APPENDIX B - DEFINITIONS 23

PART I. PERMIT COVERAGE AND LIMITATIONS

A. PERMIT COVERAGE

1. This permit is required for **storm water** discharges associated with **construction activity** and with **small construction activity** as defined in 40 C.F.R. part 122.26(b)(14)(x) and (b)(15), respectively.

2. This permit authorizes, subject to the terms and conditions of this permit, the discharge of **storm water** associated with **construction activity** and **small construction activity.**

   Construction activity includes clearing, grading and excavation, that disturbs land of equal to or greater than five (5) acres and includes the disturbance of less than five (5) acres of total land area that is a part of a larger **common plan of development or sale** if the larger common plan will ultimately disturb five (5) acres or more.

   Small construction activity includes clearing, grading and excavation, that disturbs land of equal to or greater than one (1) acre, and includes the disturbance of less than one (1) acre of total land area that is part of a larger **common plan of development or sale** if the larger common plan will ultimately disturb equal to or greater than one and less than five (5) acres. **Small construction activity** does not include routine maintenance that is performed to maintain the original line and grade, hydraulic capacity, or original purpose of the facility.

3. This permit covers all areas of the state of Minnesota.

4. For Parts I.B through Appendix A of this permit, all reference to **construction activity** includes both **small construction activity** and **construction activity**.

B. LIMITATIONS OF COVERAGE

This permit does not cover the following activities:

1. Discharges or releases that are not **storm water** except those non-**storm water** discharges authorized under Part IV.D.

2. The placement of fill into **waters of the state** requiring local, state, or federal authorizations (such as U.S. Army Corps of Engineers Section 404 permits, Department of Natural Resources Public Waters Work Permits or Local Governmental Unit Wetland Conservation Act replacement plans or determinations).

3. **Storm water** discharges associated with industrial activity that originate from the site after construction activities have been completed and the site has undergone **final stabilization**. Post-construction industrial **storm water** discharges may need to be covered by a separate NPDES/SDS permit.

4. Non-point source agricultural and silvicultural discharges excluded from **NPDES** permit requirements under 40 CFR part 122.3(e).

5. **Discharges** to the waters identified below unless the requirements of Appendix A. are complied with:

a. Discharges into outstanding resource value waters (ORVWs) as defined in Minn. R. 7050.0180, subp. 3 and 6, except calcareous fens listed in Minn. R. 7050.0180, subp. 6.b.

b. Discharges into Trout waters as listed in Minn. R. 6264.0050, subp. 2 and 4.

c. Discharges into **Wetlands** as listed in Minn. R. 7050.0130, item. F.

d. Discharges from projects that have not met applicable Environmental Review requirements under state or federal laws.

e. Discharges that adversely impact or contribute to adverse impacts on a listed endangered or threatened species or adversely modify a designated critical habitat.

f. Discharges which adversely affect properties listed or eligible for listing in the National Register of Historic Places or affecting known or discovered archeological sites.

6. Discharges to calcareous fens listed in Minn. R. 7050.0180, subp. 6.b.

7. Discharges to waters for which there is a total maximum daily load (TMDL) allocation for sediment and parameters associated with sediment transport are not eligible for coverage under this permit unless the **Permittee(s)** develop and certify a **SWPPP** that is consistent with the assumptions, allocations and requirements in the approved TMDL. To be eligible for coverage under this general permit, **Permittee(s)** must incorporate into their **SWPPP** any conditions applicable to their discharges necessary for consistency with the assumptions, allocations and requirements of the TMDL within any time frames established in the TMDL. The **SWPPP** must include the provisions in Part III.A.7. If a specific numeric wasteload allocation has been established that would apply to the project's discharges, the **Permittee(s)** must incorporate that allocation into its **SWPPP** and implement necessary steps to meet that allocation.

PART II. SUBMITTING THE APPLICATION

A. PREREQUISITE FOR SUBMITTING A PERMIT APPLICATION

The **owner** must develop a **Storm Water Pollution Prevention Plan (SWPPP)** in accordance with Part III (Storm Water Discharge Design Requirements) of this permit. The plans are not to be submitted to the MPCA (unless the project size is 50 acres or more and will discharge to certain waters as described in Part II.B.1.b.) but are to be retained by the **owner** in accordance with Part III.D (Record Retention). The applicants' failure to complete the **SWPPP** prior to submitting the application will result in the application being returned and the **storm water** discharges associated with **construction activity** will not be authorized by this permit.

B. APPLICATION AND DURATION OF COVERAGE

1. Application Required.

a. The **owner** and **operator** shall submit a completed application form (or a photocopy thereof) with the appropriate fee for project size (see application form) to the MPCA for each project which disturbs one (1) or more acres of land. The **owner** and **operator** of a **common plan of development or sale** that will ultimately disturb one (1) or more acres

must submit a completed application to the MPCA.

b. For certain projects or **common plans of development or sale** disturbing 50 acres or more, the application must be submitted at least 30 days before the start of construction activity. This requirement pertains to projects that have a discharge point on the project that is within 2000 feet of, and flows to, a special water listed in Appendix A, Part B. or waters listed as impaired under section 303(d) of the federal Clean Water Act (see MPCA's web site). Applicants must submit a completed application form and **Storm Water Pollution Prevention Plan** including all calculations for the Permanent Storm Water Management System (see Part III.A – C).

2. The **Owner** and **Operator** are **Permittee(s)**. The **owner** who signs the application is a **Permittee** and is responsible for compliance with all terms and conditions of this permit. The **operator** (usually the **general contractor**) who signs the application is a **Permittee** for Parts II.B., Part II.C. and Part IV. of this permit and is jointly responsible with the **owner** for compliance with those portions of the permit.

3. Permit Coverage. The commencement of any **construction activity** (e.g., land disturbing activities) covered under Part I.A. of this permit is prohibited until permit coverage under this permit is effective or, if applicable, until the MPCA has issued an individual NPDES/SDS construction **storm water** permit for the project.

   a. Except as provided in subp. 3.b. and 3.c. below, permit coverage will become effective seven (7) days after the postmarked date of the completed application form.

   b. For projects disturbing 50 acres or more, that have a discharge point on the project that is within 2000 feet of, and flows to, a special water listed in Appendix A, Part B. or waters listed as impaired under section 303(d) of the federal Clean Water Act, the applicants must submit a completed application and **SWPPP** to the MPCA at least thirty (30) days prior to the commencement of construction activities. MPCA staff will review the **SWPPP** submitted with the completed application and unless the **Permittee** is notified in writing that the **SWPPP** does not meet the general permit requirements, permit coverage will become effective 30 days after the postmarked date or MPCA date-stamp (whichever is first) of the completed application.

   c. For proposals to use Alternative Method(s) for the Permanent Storm Water Management System under Part III.C.5, the applicants must submit a completed application and **SWPPP**, including the Alternative Method documentation under Part III.C.5, to MPCA for review and approval at least 90 days prior to the proposed starting date of **construction activity**.

      i. The MPCA will notify the applicant within the 90-day period, in writing, whether the alternative method is approved or not approved and, if applicable, the basis for denial.
      ii. The applicant may re-submit the alternative method after addressing the MPCA's basis for denial. The MPCA will respond within 30 days.
      iii. Permit coverage will become effective upon receipt of an alternative treatment method approval letter from MPCA. Any **construction activity** on the project is not covered under this permit until receiving the alternative treatment approval letter.

4. Coverage Letter. For projects under subpart 3.a. of this part, the **Permittee(s)** will receive a permit letter and certificate acknowledging permit coverage, usually within 30 days of the postmarked date of the completed application.

5. Change of Coverage. For **storm water** discharges from construction projects where the **owner** or **operator** changes, (e.g., an original developer sells portions of the property to various home builders) the new **owner** or **operator** must submit a subdivision registration within 7 days of assuming operational control of the site, commencing work on their portion of the site, or of the legal transfer, sale or closing on the property. For instances where an **owner** or **operator** of an entire project changes after an application has been submitted under Part II, the new **owner** or **operator** must submit an application for permit transfer/modification within 7 days of assuming control of the site or commencing work on-site, or of the legal transfer, sale or closing on the property. Late submittals will not be rejected; however, the MPCA reserves the right to take enforcement for any unpermitted discharges or permit noncompliance for the new registered party that has assumed control of the site. For **storm water** discharges from construction activities where the **owner** or **operator** changes, the new **owner** or **operator** can implement the original **SWPPP** created for the project or develop and implement their own **SWPPP**. **Permittee(s)** shall ensure either directly or through coordination with other **Permittee(s)** that their **SWPPP** meets all terms and conditions of this permit and that their activities do not render another party's **erosion prevention** and **sediment control Best Management Practices (BMPs)**."

C. TERMINATION OF COVERAGE

1. **Permittee(s)** wishing to terminate coverage under this permit must submit a **Notice of Termination** (**NOT**) to the MPCA. Compliance with this permit is required until a **NOT** is submitted. The **Permittee(s)** authorization to discharge under this permit terminates at midnight of the day the **NOT** is signed.

2. All **Permittee(s)** must submit a **NOT** within thirty (30) days after one or more of the following conditions have been met:

   a. **Final stabilization** (see Part IV.G. and definition in Appendix B) has been achieved on all portions of the site for which the **Permittee** is responsible (including the removal of all temporary measures such as silt fence, and if applicable, returning agricultural land to its pre-construction agricultural use);

   b. Another **owner**/**operator** (**Permittee**) has assumed control according to Part II.B.5 over all areas of the site that have not been finally **stabilized**; or

   c. For residential construction only, **temporary erosion protection** and down gradient perimeter control for individual lots has been completed and the residence has been transferred to the homeowner. Additionally, the **Permittee** must distribute the MPCA's "**homeowner factsheet**" to the homeowner to inform the homeowner of the need for, and benefits of, **final stabilization**.

3. **Permittee(s)** that use an alternative method for the permanent **storm water** management system as described in Part III.C.5, are prohibited from terminating this permit until final stabilization has been achieved on site and either:

a. The two years of monitoring data has been submitted to the MPCA and the MPCA has determined that the required treatment has been achieved. The Permittee will be notified in writing within 30 days after the monitoring data has been submitted. If the Permittee has not heard from the MPCA within 30 days after submitting the required data, the Permittee can submit a **Notice of Termination**.

b. The Permittee can submit a **Notice of Termination**, even if the time frame is less than two years, if the MPCA determines that the alternative method is achieving the required treatment.

During the monitoring and evaluation of the alternative method, the **Permittee** is not responsible for other permit requirements that have been transferred as described in Part II.B.5.

PART III. STORM WATER DISCHARGE DESIGN REQUIREMENTS

A. STORM WATER POLLUTION PREVENTION PLAN

The **owner** must develop a **Storm Water Pollution Prevention Plan (SWPPP).** The **SWPPP** shall be completed prior to submitting any permit application and prior to conducting any **construction activity** by any required **Permittee(s)**. The plan must be a combination of narrative, plan sheets and if appropriate standard detail sheets that address the foreseeable conditions, at any stage in the construction or post construction activities. The plan must include a description of the nature of the **construction activity**. The plan must address the potential for discharge of sediment and/or other potential pollutants from the site. For **storm water** discharges from construction activities where the **owner** or **operator** changes, the new **owner** or **operator** can implement the original **SWPPP** created for the project or develop and implement their own **SWPPP**. **Permittee(s)** shall ensure either directly or through coordination with other **Permittee(s)** that their **SWPPP** meets all terms and conditions of this permit and that their activities do not render another party's **erosion prevention** and **sediment control Best Management Practices (BMPs)** ineffective.

1. As part of the **SWPPP** the **owner** must identify a person knowledgeable and experienced in the application of **erosion prevention** and **sediment control BMPs** who will oversee the implementation of the **SWPPP**, and the installation, inspection and maintenance of the **erosion prevention** and **sediment control BMPs** before and during construction. The **owner** must identify who will have the responsibility for long term operation and maintenance of the permanent **storm water** management system (see Part III.C.). The **owner** shall develop a chain of responsibility with all **operators** on the site to ensure that the **SWPPP** will be implemented and stay in effect until the construction project is complete, the entire site has undergone **final stabilization**, and a **NOT** has been submitted to the MPCA.

2. The **SWPPP** must incorporate the requirements of Part III (Storm Water Discharge Design Requirements), Part IV (Construction Activity Requirements) and Appendix A for the project. A narrative describing the timing for installation of all **erosion prevention** and **sediment control BMPs** required in Part III, Part IV and Appendix A must also be included in the plan.

3. The **SWPPP** requirements must be incorporated into the project's final plans and specifications and/or project documentation, as appropriate, and must include:

   a. Location and type of all temporary and permanent **erosion prevention** and **sediment control**

BMPs along with procedures to be used to establish additional temporary **BMPs** as necessary for the site conditions during construction. **Standard plates** and/or specifications for the **BMPs** used on the project must be included in the final plans and specifications for the project.

b. A site map with existing and final grades, including dividing lines and direction of flow for all pre and post-construction **storm water** runoff drainage areas located within the project limits. The site map must also include **impervious surfaces** and soil types.

c. Locations of areas not to be disturbed.

d. Location of areas where construction will be phased to minimize duration of exposed soil areas.

e. All **surface waters** and existing **wetlands**, which can be identified on maps such as United States Geological Survey 7.5 minute quadrangle maps or equivalent maps within one-half mile from the project boundaries, which will receive **storm water** runoff from the construction site, during or after construction. Where **surface waters** receiving runoff associated with **construction activity** will not fit on the plan sheet, they must be identified with an arrow, indicating both direction and distance to the **surface water**.

f. Methods to be used for **final stabilization** of all exposed soil areas.

4. The **Permittee(s)** must amend the **SWPPP** as necessary to include additional requirements, such as additional or modified **BMPs**, designed to correct problems identified or address situations whenever:

a. There is a change in design, construction, operation, maintenance, weather or seasonal conditions that has a significant effect on the discharge of pollutants to **surface waters** or **underground waters**;

b. Inspections or investigations by site **operators**, local, state or federal officials indicate the **SWPPP** is not effective in eliminating or significantly minimizing the discharge of pollutants to **surface waters** or **underground waters** or that the discharges are causing water quality standard exceedances**;** or

c. The **SWPPP** is not achieving the general objectives of controlling pollutants in **storm water** discharges associated with **construction activity**, or the **SWPPP** is not consistent with the terms and conditions of this permit.

d. At any time after permit coverage is effective, the MPCA may determine that the project's **storm water** discharges may cause, have reasonable potential to cause, or contribute to non-attainment of any applicable water quality standard, or that the **SWPPP** does not incorporate the requirements in Part III.A.7 related to an approved Total Maximum Daily Load (TMDL) implementation plan that contains construction **storm water** related requirements. If MPCA makes such determination(s) or any of the determinations in Parts III.A.4.a.-4.c., MPCA will notify the **Permittees** in writing. In response, the **Permittees** must develop a supplemental **BMP** action plan or appropriate **SWPPP** amendments describing **SWPPP** modifications to address the

identified concerns and submit information requested by MPCA, which may include an individual permit application. If MPCA's written notification requires a response, failure to respond within the specified time frame constitutes a permit violation.

5. The **SWPPP** must factor in any findings of and include any **storm water** mitigation measures required as the result of any environmental, archeological or other required local, state or federal review conducted for the project. For the purposes of this permit provision, mitigation measures mean avoiding, minimizing, rectifying (e.g., repairing, rehabilitating, restoring), reducing, eliminating or compensating for impacts related to: (1) **storm water** discharges associated with the project's **construction activity**; and (2) **erosion prevention**, **sediment control** and the permanent **storm water** management system for the project.

6. The **SWPPP** must provide additional measures as necessary to assure compliance with surface and ground water standards in Minn. R. chapters 7050 and 7060 in karst areas and to ensure protection of drinking water supply management areas (see Minn. R. 4725.4450).

7. If runoff from the site discharges to an impaired water which has an approved TMDL implementation plan containing requirements for construction **storm water** discharges, the **Permittee** must include the following in the SWPPP:

   a. identify the receiving water and the areas of the site discharging to it; and

   b. BMPs that are appropriate for the site and sufficient to comply with all applicable requirements of the TMDL implementation plan.

B. TEMPORARY SEDIMENT BASINS

Where ten (10) or more acres of disturbed soil drain to a common location, a temporary (or permanent) sediment basin must be provided prior to the runoff leaving the construction site or entering **surface waters**. The **Permittee** is encouraged, but not required, to install temporary sediment basins where appropriate in areas with steep slopes or highly erodible soils even if less than ten (10) acres drains to one area. The basins must be designed and constructed according to the following requirements:

1. The basins must provide storage below the outlet pipe for a calculated volume of runoff from a 2 year, 24 hour storm from each acre drained to the basin, except that in no case shall the basin provide less than 1800 cubic feet of storage below the outlet pipe from each acre drained to the basin.

2. Where no such calculation has been performed, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage below the outlet pipe per acre drained to the basin, shall be provided where attainable until **final stabilization** of the site.

3. Temporary basin outlets must be designed to prevent short-circuiting and the discharge of floating debris. The basin must be designed with the ability to allow complete basin drawdown (e.g., perforated riser pipe wrapped with filter fabric and covered with crushed gravel, pumps or other means, see Part IV.D.) for maintenance activities, and provide a **stabilized** emergency overflow to prevent failure of pond integrity. **Energy dissipation** must be provided for the basin outlet (see Part IV.B.4).

4. The temporary (or permanent) basins must be constructed and made operational concurrent with the start of soil disturbance that is upgradient of the area and contributes runoff to the pond.

5. Where the temporary sediment basin is not attainable due to site limitations, equivalent **sediment controls** such as smaller sediment basins, and/or sediment traps, silt fences, vegetative buffer strips, or any appropriate combination of measures are required for all down slope boundaries of the construction area and for those side slope boundaries deemed appropriate as dictated by individual site conditions. In determining whether installing a sediment basin is attainable, the **Permittee** must consider public safety and may consider factors such as site soils, slope, and available area on site. This determination must be documented in the **SWPPP**.

C. PERMANENT STORM WATER MANAGEMENT SYSTEM

All **storm water** must be discharged in a manner that does not cause nuisance conditions, erosion in receiving channels or on downslope properties, or inundation in **wetlands** causing a significant adverse impact to the wetlands.

Where a project's ultimate development replaces vegetation and/or other pervious surfaces with one or more acres of cumulative **impervious surface**, a **water quality volume** of ½ inch of runoff from the new **impervious surfaces** created by the project must be treated by one of the methods outlined in Part III.C.1 through Part III.C.5 prior to the runoff leaving the construction site or entering **surface waters** (excluding drainage systems that convey **storm water** to a constructed permanent **storm water** management facility designed to treat the **water quality volume** from the project).

For those areas of a project where there is no feasible way to meet the treatment requirement for the **water quality volume**, other treatment such as grassed swales, smaller ponds or grit chambers is required prior to discharge to **surface waters**. A cumulative maximum of (3) three acres or 1% of project size whichever is larger can be treated in this manner.

Where the proximity to bedrock precludes the installation of any of the permanent **storm water** management practices outlined in Part III.C., other treatment, such as grassed swales, smaller ponds, or grit chambers, is required prior to discharge to **surface waters**.

For work on road projects where the lack of right of way precludes the installation of any of the permanent **storm water** management practices outlined in Part III.C., other treatment such as grassed swales, smaller ponds, or grit chambers, is required prior to discharge to **surface waters**.

1. Wet Sedimentation Basin

   a. The basin must have a permanent volume of 1800 cubic feet of storage below the outlet pipe for each acre that drains to the basin. The basin's permanent volume must reach a minimum depth of at least 3 feet and must have no depth greater than 10 feet. The basin must be configured such that scour or resuspension of solids is minimized.

   b. The basin's **water quality volume** is calculated as ½ inch of runoff from the new **impervious surfaces** created by the project.

   c. Basin outlets shall be designed such that the **water quality volume** is discharged at no more

than 5.66 cubic feet per second (cfs) per acre of surface area of the pond.

d. Basin outlets must be designed to prevent short-circuiting and the discharge of floating debris. Basin outlets must have **energy dissipation**.

e. The basin must provide a **stabilized** emergency overflow to accommodate storm events in excess of the basin's hydraulic design.

f. Adequate maintenance access must be provided (typically 8 ft. wide) for future maintenance of the basin.

2. Infiltration/Filtration

Infiltration/Filtration options include but are not limited to: infiltration basins, infiltration trenches, rainwater gardens, sand filters, organic filters, bioretention areas, enhanced swales, dry storage ponds with underdrain discharge, off-line retention areas and natural depressions. Infiltration must be used only as appropriate to the site and land uses. Settleable solids, floating materials, oils and grease should be removed from the runoff to the maximum extent practicable before runoff enters the infiltration/filtration system. Filtration systems must have a reasonable chance of achieving approximately 80% removal of total suspended solids. The **Permittee(s)** must evaluate the impact of constructing an infiltration practice on existing hydrologic features (e.g., existing **wetlands**) and try to maintain pre-existing conditions (e.g., do not breach a perched water table which is supporting a **wetland**). For a discussion of ground water warnings, design measures, maintenance considerations or other retention, detention, and treatment devices, see the MPCA's **Protecting Water Quality in Urban Areas** found on the MPCA's web-site.

a. Infiltration systems should not be excavated to final grade until the contributing drainage area has been constructed and fully **stabilized**.

b. During construction of an infiltration system, rigorous sediment and erosion controls (e.g., diversion berms) should be used to keep sediment and runoff completely away from the infiltration area. The area must be staked off and marked so that heavy construction equipment will not compact the soil in the proposed infiltration area.

c. To prevent clogging of the infiltration or filtration system, a pretreatment device such as a vegetated filter strip, small sedimentation basin, or water quality inlet (e.g., grit chamber) must be used to settle particulates before the **storm water** discharges into the infiltration or filtration system.

d. Infiltration or filtration systems shall be sufficient to infiltrate or filter a **water quality volume** of ½ inch of runoff from the new **impervious surfaces** created by the project.

e. The **water quality volume** shall discharge through the soil or filter media in 48 hours or less. Additional flows that cannot be infiltrated or filtered in 48 hours should be routed to bypass the system through a **stabilized** discharge point. A way to visually verify that the system is operating as designed must be provided.

f. Appropriate on-site testing shall be conducted to ensure a minimum of 3 feet of separation from the seasonally **saturated soils** (or from bedrock) and the bottom of the proposed infiltration system. Calculations and computer model results that demonstrate the design

adequacy of the infiltration system must be included as part of the **SWPPP**.

g. Adequate maintenance access must be provided (typically 8 ft. wide) along with a maintenance plan identifying whom will be performing future maintenance of the infiltration or filtration system.

h. Use of designed infiltration systems from industrial areas with exposed significant materials or from vehicle fueling and maintenance areas is prohibited.

3. Regional Ponds

Regional ponds can be used provided that they are constructed ponds, not a natural **wetland** or water body, (**wetlands** used as regional ponds must be mitigated for, see Appendix A) and designed in accordance with this permit's design requirements (see Part III.C.1) for all water from **impervious surfaces** that reach the pond. **Permittees** shall not construct regional ponds in **wetlands**, regardless of their condition, quality or designation by local plans, unless the mitigative sequence in Appendix A. D.2 of this permit has been completed. There must be no significant degradation of the waterways between the project and the regional pond. The **owner** must obtain written authorization from the applicable local governmental unit (LGU) or private entity that owns and maintains the regional pond. The LGU's or private entity's written authorization must identify that the regional pond will discharge the **water quality volume** (½ inch of runoff from the impervious watershed area) at no more than 5.66 cfs per acre of surface area of the pond. The **owner** must include the LGU's or private entity's written authorization in the **SWPPP**. The LGU's or private entity's written authorization must be obtained before the **owner** finalizes the **SWPPP** and before any application for this permit is made to the MPCA.

4. Combination of Practices

A combination of practices, including those required by a LGU, which meet the requirements of Part III.C.1, 2 and 3 respectively, (i.e., wet sedimentation basins, infiltration/filtration, and regional ponds) may be used such that the **water quality volume** of ½ inch of runoff from the new **impervious surfaces** created by the project is accounted for in the **owner's** permanent **storm water** management system (e.g., ¼ inch infiltrated and ¼ inch treated through a wet sedimentation basin). If any combination of these practices is used, the **SWPPP** must contain documentation (e.g., LGU or private entity's authorization, infiltration computer model results or calculations, etc.) identifying the volume that each practice addresses.

5. Alternative Method

Where an alternative, innovative treatment system is proposed and demonstrated by calculation, design or other independent methods to achieve approximately 80% removal of total suspended solids on an annual average basis, the **Commissioner** will approve the method if the process outlined in Part II.B.3.c. is completed, and the following information is submitted:

a. All calculations, drainage areas, plans, and specifications for the proposed alternative method and a graphic representation of the area to be served by the method. These items must be included in the **SWPPP** and submitted to the MPCA at least 90 days prior to the proposed starting date of the **construction activity**.

b. A 2 year monitoring plan to sample runoff from the proposed method. The plan must include a discussion of the methods used to collect samples, location where samples will be taken (upstream and downstream of the proposed method), frequency of samples (minimum of six runoff events sampled), identify lab used to analyze the samples and quality assurance and quality control methods to be used. The plan must include a schedule for submitting the monitoring data annually.

c. A mitigation plan that addresses how the **water quality volume** will be treated in the event that the monitoring data shows the proposed alternative treatment method does not function as designed.

d. The alternative method must achieve approximately 80% removal of total suspended solids on an average annual basis for the conditions expected at the site. The design must also consider public safety, health and water quality concerns. Proprietary information on effectiveness will not be considered for alternative treatment method review and approval.

No **construction activity** on the project is covered under this permit until the applicant receives an alternative treatment approval letter from the MPCA as described in Part II.B.3.c.

D. RECORD RETENTION

The **SWPPP**, all changes to it, and inspections and maintenance records must be kept at the site during construction by the **Permittee** who has operational control of that portion of the site. The **SWPPP** can be kept in either the field office or in an on site vehicle.

All **owner(s)** must keep the **SWPPP**, along with the following additional records, on file for three years after submittal of the **NOT** as outlined in Part II.C. This does not include any records after submittal of the **NOT**.

1. Any other permits required for the project;

2. Records of all inspection and maintenance conducted during construction (see Part IV.E. Inspections and Maintenance);

3. All permanent operation and maintenance agreements that have been implemented, including all right of way, contracts, covenants and other binding requirements regarding perpetual maintenance; and

4. All required calculations for design of the temporary and permanent **storm water** management systems.

PART IV. CONSTRUCTION ACTIVITY REQUIREMENTS

A. STORM WATER POLLUTION PREVENTION PLAN

The **Permittee(s)** must implement the **SWPPP** and the requirements of this part. The **Best Management Practices (BMPs)** identified in the **SWPPP** and in this permit must be installed in an appropriate and functional manner.

B. EROSION PREVENTION PRACTICES

1. The **Permittee(s)** must plan for and implement appropriate construction phasing, vegetative buffer strips, horizontal slope grading, and other construction practices that minimize erosion, so that the inspection and maintenance requirements of Part IV.E. are complied with. The location of areas not to be disturbed must be delineated (e.g. with flags, stakes, signs, silt fence etc.) on the development site before work begins.

2. All exposed soil areas with a continuous positive slope within 200 lineal feet of a **surface water,** must have **temporary erosion protection** or **permanent cover** for the exposed soil areas year round, according to the following table of slopes and time frames:

Type of Slope	Time	(Maximum time an area can remain open when the area is not actively being worked.)
Steeper than 3:1	7 days	
10:1 to 3:1	14 days	
Flatter than 10:1	21 days	

These areas include constructed **storm water** management pond side slopes, and any exposed soil areas with a positive slope to a **storm water** conveyance system, such as a curb and gutter system, storm sewer inlet, temporary or permanent drainage ditch or other natural or man made systems that discharge to a **surface water**. Temporary stockpiles without significant silt, clay or organic components (e.g., clean aggregate stockpiles, demolition concrete stockpiles, sand stockpiles) are exempt from this requirement but must comply with Part IV.C.5.

3. The **normal wetted perimeter** of any temporary or permanent drainage ditch that drains water from a construction site, or diverts water around a site, must be **stabilized** within 200 lineal feet from the property edge, or from the point of discharge to any **surface water.** Stabilization must be completed within 24 hours of connecting to a **surface water.**

4. Pipe outlets must be provided with temporary or permanent **energy dissipation** within 24 hours of connection to a **surface water**.

C. SEDIMENT CONTROL PRACTICES

1. **Sediment control** practices must minimize sediment from entering **surface waters**, including curb and gutter systems and storm sewer inlets.

a. Temporary or permanent drainage ditches and sediment basins that are designed as part of a treatment system (e.g., ditches with rock check dams) require **sediment control** practices only as appropriate for site conditions.

b. If the down gradient treatment system is overloaded, additional upgradient **sediment control** practices must be installed to eliminate the overloading, and the **SWPPP** must be amended to identify these additional practices as required in Part III.A.4, a. through c.

c. In order to maintain sheet flow and minimize rills and/or gullies, there shall be no unbroken slope length of greater than 75 feet for slopes with a grade of 3:1 or steeper.

2. **Sediment control** practices must be established on all down gradient perimeters before any upgradient land disturbing activities begin. These practices shall remain in place until **final stabilization** has been established in accordance with Part IV.G.

3. The timing of the installation of **sediment control** practices may be adjusted to accommodate short-term activities such as clearing or grubbing, or passage of vehicles. Any short-term activity must be completed as quickly as possible and the **sediment control** practices must be installed immediately after the activity is completed. However, **sediment control** practices must be installed before the next precipitation event even if the activity is not complete.

4. All storm drain inlets must be protected by appropriate **BMPs** during construction until all sources with potential for discharging to the inlet have been **stabilized**.

5. Temporary soil stockpiles must have silt fence or other effective **sediment controls**, and cannot be placed in **surface waters**, including **storm water** conveyances such as curb and gutter systems, or conduits and ditches**.**

6. Vehicle tracking of sediment from the construction site must be minimized by **BMPs** such as stone pads, concrete or steel wash racks, or equivalent systems. Street sweeping must be used if such **BMPs** are not adequate to prevent sediment from being tracked onto the street (see Part IV.E.4.d.).

7. The **Permittee** must install temporary sedimentation basins as required in Part III.B. of this permit.

D. DEWATERING AND BASIN DRAINING

1. **Dewatering** or basin draining (e.g., pumped discharges, trench/ditch cuts for drainage) related to the **construction activity** that may have turbid or sediment laden discharge water must be discharged to a temporary or permanent sedimentation basin on the project site whenever possible. If the water cannot be discharged to a sedimentation basin prior to entering the **surface water**, it must be treated with the appropriate **BMPs**, such that the discharge does not adversely affect the receiving water or downstream landowners. The **Permittee(s)** must ensure that discharge points are adequately protected from erosion and scour. The discharge must be dispersed over natural rock riprap, sand bags, plastic sheeting or other accepted **energy dissipation** measures. Adequate sedimentation control measures are required for discharge water that contains suspended solids.

2. All water from **dewatering** or basin draining activities must be discharged in a manner that does not cause nuisance conditions, erosion in receiving channels or on downslope properties, or inundation in **wetlands** causing significant adverse impact to the **wetland.**

E. INSPECTIONS AND MAINTENANCE

1. The **Permittee(s)** (either the **owner** or **operator**, whoever is identified in the **SWPPP**) must routinely inspect the construction site once every seven (7) days during active construction and within 24 hours after a rainfall event greater than 0.5 inches in 24 hours.

2. All inspections and maintenance conducted during construction must be recorded in writing and

these records must be retained with the **SWPPP** in accordance with Part III.D. Records of each inspection and maintenance activity shall include:

a. Date and time of inspections;

b. Name of person(s) conducting inspections;

c. Findings of inspections, including recommendations for corrective actions;

d. Corrective actions taken (including dates, times, and party completing maintenance activities);

e. Date and amount of all rainfall events greater than 1/2 inch (0.5 inches) in 24 hours; and

f. Documentation of changes made to the **SWPPP** as required in Part III.A.4.

3. Where parts of the construction site have undergone **final stabilization**, but work remains on other parts of the site, inspections of the **stabilized** areas may be reduced to once per month. Where work has been suspended due to frozen ground conditions, the required inspections and maintenance must take place as soon as runoff occurs at the site or prior to resuming construction, whichever comes first.

4. All **erosion prevention** and **sediment control BMPs** must be inspected to ensure integrity and effectiveness. All nonfunctional **BMPs** must be repaired, replaced, or supplemented with functional **BMPs**. The **Permittee(s)** must investigate and comply with the following inspection and maintenance requirements:

a. All silt fences must be repaired, replaced, or supplemented when they become nonfunctional or the sediment reaches 1/3 of the height of the fence. These repairs must be made within 24 hours of discovery, or as soon as field conditions allow access.

b. Temporary and permanent sedimentation basins must be drained and the sediment removed when the depth of sediment collected in the basin reaches 1/2 the storage volume. Drainage and removal must be completed within 72 hours of discovery, or as soon as field conditions allow access (see Part IV.D.).

c. **Surface waters**, including drainage ditches and conveyance systems, must be inspected for evidence of sediment being deposited by erosion. The **Permittee(s)** must remove all deltas and sediment deposited in **surface waters**, including drainage ways, catch basins, and other drainage systems, and restabilize the areas where sediment removal results in exposed soil. The removal and stabilization must take place within seven (7) days of discovery unless precluded by legal, regulatory, or physical access constraints. The **Permittee** shall use all reasonable efforts to obtain access. If precluded, removal and stabilization must take place within seven (7) calendar days of obtaining access. The **Permittee** is responsible for contacting all local, regional, state and federal authorities and receiving any applicable permits, prior to conducting any work.

d. Construction site vehicle exit locations must be inspected for evidence of off-site sediment tracking onto paved surfaces. Tracked sediment must be removed from all off-site paved

surfaces, within 24 hours of discovery, or if applicable, within a shorter time to comply with Part IV.C.6.

e. The **Permittee(s)** are responsible for the operation and maintenance of temporary and permanent water quality management **BMPs**, as well as all **erosion prevention** and **sediment control BMPs**, for the duration of the construction work at the site. The **Permittee(s)** are responsible until another **Permittee** has assumed control according to Part II.B.5 over all areas of the site that have not been finally **stabilized** or the site has undergone **final stabilization**, and a **NOT** has been submitted to the MPCA.

f. If sediment escapes the construction site, off-site accumulations of sediment must be removed in a manner and at a frequency sufficient to minimize off-site impacts (e.g., fugitive sediment in streets could be washed into storm sewers by the next rain and/or pose a safety hazard to users of public streets).

5. All infiltration areas must be inspected to ensure that no sediment from ongoing **construction activities** is reaching the infiltration area and these areas are protected from compaction due to construction equipment driving across the infiltration area.

F. POLLUTION PREVENTION MANAGEMENT MEASURES

The **Permittee(s)** shall implement the following pollution prevention management measures on the site:

1. Solid Waste: Collected sediment, asphalt and concrete millings, floating debris, paper, plastic, fabric, construction and demolition debris and other wastes must be disposed of properly and must comply with MPCA disposal requirements.

2. Hazardous Materials: Oil, gasoline, paint and any hazardous substances must be properly stored, including secondary containment, to prevent spills, leaks or other discharge. Restricted access to storage areas must be provided to prevent vandalism. Storage and disposal of hazardous waste must be in compliance with MPCA regulations.

3. External washing of trucks and other construction vehicles must be limited to a defined area of the site. Runoff must be contained and waste properly disposed of. No engine degreasing is allowed on site.

G. FINAL STABILIZATION

The **Permittee(s)** must ensure **final stabilization** of the site. The **Permittee(s)** must submit a **NOT** within 30 days after **final stabilization** is complete, or another **owner/operator** (**Permittee**) has assumed control according to Part II.B.5 over all areas of the site that have not undergone **final stabilization**. **Final stabilization** can be achieved in one of the following ways:

1. All soil disturbing activities at the site have been completed and all soils must be **stabilized** by a uniform perennial vegetative cover with a density of 70 percent over the entire pervious surface area, or other equivalent means necessary to prevent soil failure under erosive conditions and;

a. All drainage ditches, constructed to drain water from the site after construction is complete,

must be **stabilized** to preclude erosion;

b. All temporary synthetic, and structural **erosion prevention** and **sediment control BMPs** (such as silt fence) must be removed as part of the site **final stabilization;** and

c. The **Permittee(s)** must clean out all sediment from conveyances and from temporary sedimentation basins that are to be used as permanent water quality management basins. Sediment must be **stabilized** to prevent it from being washed back into the basin, conveyances or drainageways discharging off-site or to **surface waters**. The cleanout of permanent basins must be sufficient to return the basin to design capacity.

2. For residential construction only, **final stabilization** has been achieved when **temporary erosion protection** and down gradient perimeter control for individual lots has been completed and the residence has been transferred to the homeowner. Additionally, the **Permittee** must distribute the MPCA **"homeowner fact sheet"** to the homeowner to inform the homeowner of the need for, and benefits of, **final stabilization**.

PART V. GENERAL PROVISIONS

A. APPLICABILITY CRITERIA

1. If the **Commissioner** determines that **storm water** discharges associated with a **construction activity** are contributing to a violation of a water quality standard or would be more appropriately regulated by an individual permit, the **Commissioner** may require the **owner** to be covered by an individual **storm water** discharge permit. The **Commissioner** may require the **owner** to develop and implement specific **BMPs** and monitor the discharge from the site. If applicable, upon issuance of an individual permit, this general permit would no longer apply.

2. If the terms and conditions of this general permit cannot be met, an **owner** may request an individual permit, in accordance with Minn. R. 7001.

B. RESPONSE

The **SWPPP**, including all certificates, reports, records, or other information required by this permit, must be made available to federal, state, and local officials within 72 hours upon request for the duration of the permit and for three years following the **NOT**. This does not include any records after submittal of the **NOT**.

C. PROHIBITIONS

This permit prohibits discharges of any material other than **storm water,** and discharges from **dewatering** or basin draining activities in accordance with Part IV.D.1 and 2. For example, prohibited discharges include but are not limited to vehicle and equipment washing, maintenance spills, wash water, and discharges of oil and other hazardous substances.

D. TRANSFER OF OWNERSHIP OR CONTROL

This permit may not be assigned or transferred by the permit holder except when transfer occurs in accordance with the applicable requirements of Part II.B.5.

E. CIVIL AND CRIMINAL LIABILITY

Nothing in this permit must be construed to relieve the **Permittee(s)** from civil or criminal penalties for noncompliance with the terms and conditions provided herein. Nothing in this permit must be construed to preclude the initiation of any legal action or relieve the **Permittee(s)** from any responsibilities, liabilities, or penalties to which the **Permittee(s)** is or may be subject to under Section 311 of the Act and Minn. Stat. chs. 115 and 116, as amended. The **Permittee(s)** are not liable for permit requirements for activities occurring on those portions of a site where another party has submitted a subdivision short form registration as described in Part II. B.5 or a **NOT** has been issued by the MPCA except for responsibilities listed under Part III.C.5 if applicable.

F. SEVERABILITY

The provisions of this permit are severable. If any provision of this permit, or the application of any provision of this permit to any circumstances, is held invalid, the application of such provision to other circumstances, and the remainder of this permit must not be affected thereby.

G. NPDES/SDS RULE STANDARD CONDITIONS

The **Permittee(s)** must comply with the provisions of Minn. R. 7001.0150, subp. 3 and 7001.1090, subp. 1.A,B,C,H,I. This permit does not require the submittal of a data monitoring report, except where monitoring is required in Part III.C.5.

H. INSPECTION AND ENTRY

The **Permittee(s)** must comply with the provisions of 40 CFR 122.41(i), Minn. Stat. Ch. 115.04 and Minn. Stat. Ch. 115B.17. The **Permittee(s)** shall allow representatives of the MPCA or any member, employee or agent thereof, when authorized by it, upon presentation of credentials, to enter upon any property, public or private, for the purpose of obtaining information or examination of records or conducting surveys or investigations.

APPENDIX A

A. GENERAL REQUIREMENTS

All requirements in this Appendix are in addition to **BMPs** already specified in the permit. Where provisions of Appendix A conflict with requirements elsewhere in the permit, the provisions in Appendix A take precedence. All **BMPs** used to comply with this Appendix must be documented in the **SWPPP** for the project. If the terms and conditions of this Appendix cannot be met, an individual permit will be required in accordance with Minn. R. ch. 7001.

B. REQUIREMENTS FOR DISCHARGES TO SPECIAL WATERS

Additional **BMPs** together with enhanced runoff controls**,** are required for discharges to the following special waters (part B.1 through B.8 of Appendix A). The **BMPs** identified for each special water are required for those areas of the project draining to a discharge point on the project that is within 2000 feet of a special water and flows to that special water.

1. **Wilderness areas:** Boundary Waters Canoe Area Wilderness; Voyageurs National Park; Kettle River from the site of the former dam at Sandstone to its confluence with the Saint Croix River; Rum River from Ogechie Lake spillway to the northernmost confluence with Lake Onamia. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2, C.3 and C.4 of this appendix.

2. **Mississippi River:** Those portions from Lake Itasca to the southerly boundary of Morrison County that are included in the Mississippi Headwaters Board comprehensive plan dated February 12, 1981. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2 and C.3 of this appendix.

3. **Scenic or recreational river segments:** Saint Croix river, entire length; Cannon River from northern city limits of Faribault to its confluence with the Mississippi River; North Fork of the Crow River from Lake Koronis outlet to the Meeker-Wright county line; Kettle River from north Pine County line to the site of the former dam at Sandstone; Minnesota River from Lac qui Parle dam to Redwood County state aid highway 11; Mississippi River from county state aid highway 7 bridge in Saint Cloud to northwestern city limits of Anoka; and Rum River from state aid Highway 27 bridge in Onamia to Madison and Rice streets in Anoka. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2 and C.3 of this appendix.

4. **Lake Superior:** (prohibited and restricted) Discharges to Lake Superior must incorporate the **BMPs** outlined in C.1, C.2 and C.3 of this appendix.

5. **Lake Trout Lakes:** Identified in Minn. R. 7050.0470, including those inside the boundaries of the Boundary Waters Canoe Area Wilderness and Voyageurs National Park. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2, C.3 and C.4 of this appendix.

6. **Trout Lakes:** identified in Minn. R. 6264.0050, subp. 2. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2, C.3, and C.4 of this appendix.

7. **Scientific and natural areas:** Boot Lake, Anoka County; Kettle River in sections 15, 22, 23, T 41 N, R 20, Pine County; Pennington Bog, Beltrami County; Purvis Lake-Ober Foundation, Saint Louis County; Waters within the borders of Itasca Wilderness Sanctuary, Clearwater County; Iron Springs Bog, Clearwater County; Wolsfeld Woods, Hennepin County; Green Water Lake, Becker County; Blackdog Preserve, Dakota County; Prairie Bush Clover, Jackson County; Black Lake Bog, Pine County; Pembina Trail Preserve, Polk County; and Falls Creek, Washington County. Discharges to these waters must incorporate the **BMPs** outlined in C.1, C.2, C.3 and C.4 of this appendix.

8. **Trout Streams:** listed in Minn. R. 6264.0050, subp. 4. Discharges to these waters must incorporate the **BMPs** outlined in Appendix A C.1, C.2, C.3, and C.5 of this appendix.

C. ADDITIONAL BMPS FOR SPECIAL WATERS

For the BMPs described in C.2, C.4 and C.5 of this Appendix:

Where the proximity to bedrock precludes the installation of any of the permanent **storm water** management practices outlined in Appendix A, other treatment such as grassed swales, smaller ponds, or grit chambers is required prior to discharge to **surface waters**.

For work on road projects where the lack of right of way precludes the installation of any of the permanent **storm water** management practices outlined in Appendix A, other treatment such as grassed swales, smaller ponds, or grit chambers is required prior to discharge to **surface waters**.

1. During construction.

    a. All exposed soil areas with a slope of 3:1 or steeper, that have a continuous positive slope to a special water must have **temporary erosion protection** or **permanent cover** within 3 days after the area is no longer actively being worked. All other slopes that have a continuous positive slope to a special water must have **temporary erosion protection** or **permanent cover** within 7 days after the area is no longer actively being worked.

    b. Temporary sediment basin requirements described in Part III.B.1-5 must be used for common drainage locations that serve an area with five (5) or more acres disturbed at one time.

2. Post construction. The **water quality volume** that must be treated by the project's permanent **storm water** management system described in Part III.C. shall be one (1) inch of runoff from the new **impervious surfaces** created by the project.

3. Buffer zone. An undisturbed buffer zone of not less than 100 linear feet from the special water (not including tributaries) shall be maintained at all times. Exceptions from this requirement for areas, such as water crossings or limited water access, are allowed if the **Permittee** fully documents in the **SWPPP** the circumstances and reasons that the buffer encroachment is necessary. All potential water quality, scenic and other environmental impacts of these exceptions must be minimized and documented in the **SWPPP** for the project.

4. Enhanced runoff controls. The permanent **storm water** management system must be designed such that the pre and post project runoff rate and volume from the 1, and 2-year 24-hour precipitation events remains the same.

5. Temperature Controls. The permanent **storm water** management system must be designed such that the discharge from the project will minimize any increase in the temperature of trout stream receiving waters resulting from the 1, and 2-year 24-hour precipitation events. This includes all tributaries of designated trout streams within the section that the trout stream is located. Projects that discharge to trout streams must minimize the impact using one or more of the following measures, in order of preference:

    a. Minimize new **impervious surfaces**.
    b. Minimize the discharge from connected **impervious surfaces** by discharging to vegetated areas, or grass swales, and through the use of other non-structural controls.
    c. Infiltration or evapotranspiration of runoff in excess of pre-project conditions (up to the 2-year 24-hour precipitation event).
    d. If ponding is used, the design must include an appropriate combination of measures such as shading, filtered bottom withdrawal, vegetated swale discharges or constructed **wetland** treatment cells that will limit temperature increases. The pond should be designed to draw down in 24 hours or less.
    e. Other methods that will minimize any increase in the temperature of the trout stream.

D. REQUIREMENTS FOR DISCHARGING TO WETLANDS

If the project has any **storm water** discharges with the potential for significant adverse impacts to a **wetland** (e.g., conversion of a natural **wetland** to a **storm water** pond) , the **Permittee(s)** must demonstrate that the **wetland** mitigative sequence has been followed in accordance with D.1 or D.2 of this appendix.

1. If the potential adverse impacts to a **wetland** on a specific project site have been addressed by permits or other approvals from an official statewide program (U.S. Army Corps of Engineers 404 program, Minnesota Department of Natural Resources, or the State of Minnesota Wetland Conservation Act) that are issued specifically for the project and project site, the **Permittee** may use the permit or other determination issued by these agencies to show that the potential adverse impacts have been addressed. For the purposes of this permit, deminimus actions are determinations by the permitting agency that address the project impacts, whereas a non-jurisdictional determination does not address project impacts.

2. If there are impacts from the project that are not addressed in one of the permits or other determinations discussed in Appendix A, Part D.1 (e.g., permanent inundation or flooding of the **wetland**, significant degradation of water quality, excavation, filling, draining), the **Permittee** must minimize all adverse impacts to **wetlands** by utilizing appropriate measures. Measures used must be based on the nature of the **wetland**, its vegetative community types and the established hydrology. These measures include in order of preference:

   a. Avoid all significant adverse impacts to **wetlands** from the project and post project discharge.

   b. Minimize any unavoidable impacts from the project and post project discharge.

   c. Provide compensatory mitigation when the **Permittee** determines that there is no reasonable and practicable alternative to having a significant adverse impact on a **wetland**. For compensatory mitigation, wetland restoration or creation shall be of the same type, size and whenever reasonable and practicable in the same watershed as the impacted wetland.

E. DISCHARGES REQUIRING ENVIRONMENTAL REVIEW

This permit does not replace or satisfy any environmental review requirements, including those under the Minnesota Environmental Policy Act (MEPA) or the National Environmental Policy Act (NEPA). The **owner** must complete any environmental review required by law, including any required Environmental Assessment Work Sheets or Environmental Impact Statements, Federal environmental review, or other required review.

F. DISCHARGES AFFECTING ENDANGERED OR THREATENED SPECIES

This permit does not replace or satisfy any review requirements for Endangered or Threatened species, from new or **expanded discharges** that adversely impact or contribute to adverse impacts on a listed endangered or threatened species or adversely modify a designated critical habitat. The **owner** must conduct any required review and coordinate with appropriate agencies for any project with the potential of affecting threatened or endangered species, or their critical habitat.

G. DISCHARGES AFFECTING HISTORIC PLACES OR ARCHEOLOGICAL SITES

This permit does not replace or satisfy any review requirements for Historic Places or Archeological Sites, from new or **expanded discharges** which adversely affect properties listed or eligible for listing in the National Register of Historic Places or affecting known or discovered Archeological Sites. The **owner** must be in compliance with National Historic Preservation Act and conduct all required review and coordination related to historic preservation, including significant anthropological sites and any burial sites, with the Minnesota Historic Preservation Officer.

APPENDIX B. DEFINITIONS

1. "**Best Management Practices (BMPs)**" means erosion and **sediment control** and water quality management practices that are the most effective and practicable means of controlling, preventing, and minimizing degradation of **surface water**, including avoidance of impacts, construction-phasing, minimizing the length of time soil areas are exposed, prohibitions, and other management practices published by state or designated area-wide planning agencies.

   Individual **BMPs** found in this permit are described in the current version of **Protecting Water Quality in Urban Areas**, Minnesota Pollution Control Agency 2000. **BMPs** must be adapted to the site and can be adopted from other sources. However, they must be similar in purpose and at least as effective and stringent as MPCA's **BMPs**. (Other sources include manufacturers specifications, **Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices**, U.S. Environmental Protection Agency 1992, and **Erosion Control Design Manual**, Minnesota Department of Transportation, et al, 1993).

2. **"Commissioner"** means the **Commissioner** of the Minnesota Pollution Control Agency or the **Commissioner's** designee.

3. **"Common Plan of Development or Sale"** means a contiguous area where multiple separate and distinct land disturbing activities may be taking place at different times, on different schedules, but under one proposed plan. One plan is broadly defined to include design, permit application, advertisement or physical demarcation indicating that land-disturbing activities may occur.

4. "**Construction Activity**" For this permit, **construction activity** includes **construction activity** as defined in 40 C.F.R. part 122.26(b)(14)(x) and **small construction activity** as defined in 40 C.F.R. part 122.26(b)(15). This includes a disturbance to the land that results in a change in the topography, existing soil cover (both vegetative and non-vegetative), or the existing soil topography that may result in accelerated **storm water** runoff, leading to soil erosion and movement of sediment into **surface waters** or drainage systems. Examples of construction activity may include clearing, grading, filling and excavating. **Construction activity** includes the disturbance of less than one acre of total land area that is a part of a larger **common plan of development or sale** if the larger common plan will ultimately disturb one (1) acre or more.

5. **"Dewatering**" means the removal of water for **construction activity**. It can be a discharge of appropriated surface or groundwater to dry and/or solidify a construction site. It may require Minnesota Department of Natural Resources permits to be appropriated and if contaminated may require other MPCA permits to be discharged.

6. "**Energy Dissipation**" means methods employed at pipe outlets to prevent erosion. Examples include, but are not limited to: concrete aprons, riprap, splash pads, and gabions that are designed to prevent erosion.

7. **"Erosion Prevention"** means measures employed to prevent erosion including but not limited to: soil stabilization practices, limited grading, mulch, temporary or **permanent cover**, and construction phasing.

8. "**Final Stabilization**" means that either:
   a. All soil disturbing activities at the site have been completed and a uniform (e.g., evenly distributed, without large bare areas) perennial vegetative cover with a density of 70% of the native background vegetative cover for the area has been established on all unpaved areas and areas not covered by permanent structures, or equivalent permanent stabilization measures (such as the use of riprap, gabions, or geotextiles) have been employed;

   b. For individual lots in residential construction by either: (a) The home builder completing **final stabilization** as specified above, or (b) the home builder establishing temporary stabilization including perimeter controls for an individual lot prior to occupation of the home by the homeowner and informing the homeowner of the need for, and benefits of, **final stabilization**. (Homeowners typically have an incentive to put in the landscaping functionally equivalent to **final stabilization** as quick as possible to keep mud out of their homes and off sidewalks and driveways.); or

   c. For construction projects on land used for agricultural purposes (e.g., pipelines across crop or range land) **final stabilization** may be accomplished by returning the disturbed land to its preconstruction agricultural use. Areas disturbed that were not previously used for agricultural activities, such as buffer strips immediately adjacent to **surface waters** and drainage systems, and areas which are not being returned to their preconstruction agricultural use must meet the **final stabilization** criteria in (a) or (b) above.

9. "**General Contractor**" means the party who signs the construction contract with the **owner** to construct the project described in the final plans and specifications. Where the construction project involves more than one contractor, the **general contractor** will be the party responsible for managing the project on behalf of the **owner**. In some cases, the **owner** may be the **general contractor**. In these cases, the **owner** may contract an individual as the **operator** who would become the Co-Permittee.

10. "**Homeowner Fact sheet"** means a fact sheet developed by the MPCA to be given to homeowners at the time of sale by a builder to inform the homeowner of the need for, and benefits of, **final stabilization**.

11. "**Impervious Surface**" means a constructed hard surface that either prevents or retards the entry of water into the soil and causes water to run off the surface in greater quantities and at an increased rate of flow than prior to development. Examples include rooftops, sidewalks, patios, driveways, parking lots, storage areas, and concrete, asphalt, or gravel roads.

12. "**National Pollutant Discharge Elimination System (NPDES)**" means the program for issuing, modifying, revoking, reissuing, terminating, monitoring, and enforcing permits under the Clean Water Act (Sections 301, 318, 402, and 405) and United States Code of Federal Regulations Title 33, Sections 1317, 1328, 1342, and 1345..

13. "**Normal Wetted Perimeter**" means the area of a conveyance, such as a ditch, channel, or pipe that is in contact with water during flow events that are expected to occur once every year.

14. "**Notice of Termination**" means notice to terminate coverage under this permit after construction is complete, the site has undergone **final stabilization**, and maintenance agreements for all permanent facilities have been established, in accordance with all applicable conditions of this permit. **Notice of Termination** forms are available from the MPCA.

15. **"Operator"** means the person (usually the **general contractor**), designated by the **owner**, who has day to day operational control and/or the ability to modify project plans and specifications related to the **SWPPP**. The person must be knowledgeable in those areas of the permit for which the **operator** is responsible, (Part II.B. and Part IV.) and must perform those responsibilities in a workmanlike manner.

16. "**Owner**" means the person or party possessing the title of the land on which the construction activities will occur; or if the **construction activity** is for a lease holder, the party or individual identified as the lease holder; or the contracting government agency responsible for the **construction activity**.

17. "**Permanent Cover**" means **final stabilization**. Examples include grass, gravel, asphalt, and concrete.

18. "**Permittee**" means a person or persons, firm, or governmental agency or other institution that signs the application submitted to the MPCA and is responsible for compliance with the terms and conditions of this permit.

19. **"Saturated Soil"** means the highest seasonal elevation in the soil that is in a reduced chemical state because of soil voids being filled with water. **Saturated soil** is evidenced by the presence of redoximorphic features or other information.

20. "**Sediment Control**" means methods employed to prevent sediment from leaving the site. **Sediment control** practices include silt fences, sediment traps, earth dikes, drainage swales, check dams, subsurface drains, pipe slope drains, storm drain inlet protection, and temporary or permanent sedimentation basins.

21. "**Small Construction Activity**" means small construction activity as defined in 40 C.F.R. part 122.26(b)(15) . Small construction activities include clearing, grading and excavating that result in land disturbance of equal to or greater than one acre and less than five acres. **Small construction activity** includes the disturbance of less than one (1) acre of total land area that is part of a larger **common plan of development or sale** if the larger common plan will ultimately disturb equal to or greater than one and less than five (5) acres.

22. "**Stabilized**" means the exposed ground surface has been covered by appropriate materials such as mulch, staked sod, riprap, wood fiber blanket, or other material that prevents erosion from occurring. Grass seeding is not stabilization.

23. "**Standard Plates**" means general drawings having or showing similar characteristics or qualities that are representative of a construction practice or activity.

24. "**Storm water**" is defined under Minn. R. 7077.0105, subp. 41(b), and includes precipitation runoff, **storm water** runoff, snow melt runoff, and any other surface runoff and drainage.

25. **"Storm Water Pollution Prevention Plan"** means a plan for **storm water** discharge that includes **erosion prevention** measures and **sediment controls** that, when implemented, will decrease soil erosion on a parcel of land and decrease off-site nonpoint pollution.

26. **"Surface Water or Waters"** means all streams, lakes, ponds, marshes, **wetlands**, reservoirs, springs, rivers, drainage systems, waterways, watercourses, and irrigation systems whether natural or artificial, public or private.

27. "**Temporary Erosion Protection**" means methods employed to prevent erosion. Examples of temporary cover include; straw, wood fiber blanket, wood chips, and erosion netting.

28. "**Underground Waters**" means water contained below the surface of the earth in the saturated zone including, without limitation, all waters whether under confined, unconfined, or perched conditions, in near surface unconsolidated sediment or regolith, or in rock formations deeper underground. The term ground water shall be synonymous with underground water.

29. "Waters of the State" (as defined in Minn. Stat. § 115.01, subd. 22) means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, reservoirs, aquifers, irrigation systems, drainage systems and all other bodies or accumulations of water, surface or underground, natural or artificial, public or private, which are contained within, flow through, or border upon the state or any portion thereof.

30. "Water Quality Volume" means ½ inch of runoff from the new **impervious surfaces** created by this project and is the volume of water to be treated in the permanent **storm water** management system, as required by this permit except as provided in Appendix A.C.2.

31. "Wetland" or "Wetlands" is defined in Minn. R. 7050.0130, subp. F and includes those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in **saturated soil** conditions. **Wetlands** generally include swamps, marshes, bogs, and similar areas. Constructed **wetlands** designed for wastewater treatment are not **waters of the state**. **Wetlands** must have the following attributes:

a. A predominance of hydric soils;

b. Inundated or saturated by **surface water** or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in a **saturated soil** condition; and

c. Under normal circumstances support a prevalence of such vegetation.